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Professor of Chemistry in the Woman's Medical College of Pennsylvania,
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FOURTH EDITION, REVISED.

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PREFACE TO FOURTH EDITION.

In preparing this edition I have kept the general arrangement of the work unchanged. The adoption of the revised spelling is the most important alteration. The chapter on the Urine has been largely re-written, and I have embodied in it several of the important results obtained by Dr. D. D. Stewart in his study of tests for albumin and its congeners.

H. L.

715 WALNUT ST., PHILA.
October, 1894.

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COMPEND OF CHEMISTRY.

ELEMENTS.

Chemistry is the science that investigates the composition of matter and the changes that take place in it.

Matter is anything that occupies space and has weight.

Changes may be *physical* or *chemical*. *Physical change* is in general that which occurs without change of composition. The most frequent instances of true physical change are those known as *changes of state*. Matter exists in at least three states—the solid, liquid and gaseous. The conversion of a body from one of these conditions to the other takes place under the influence of change of temperature, and is not necessarily attended by any alteration of composition. Such is the case in the conversion of ice into water, or water into steam, or the reverse. The development of magnetic properties in iron is another example of a physical change. In many cases the conversion of a solid into a liquid, or of a liquid into a gas, is attended by change of composition, and, therefore, is not merely a physical change. *Chemical change* is that attended by alteration of composition. The rusting of iron, burning of coal, rotting of animal and vegetable matter, are familiar instances of chemical change.

Forms of Chemical Change.—These are combination, decomposition, and re-arrangement. Combination is the association of bodies to form a new substance. Decomposition is the separation of a body into new substances. Re-arrangement refers to cases in which new bodies are formed without combination or decomposition. Decomposition cannot be carried on indefinitely. No matter what substance is taken for experiment, there will ultimately be reached bodies which are incapable of further decomposition by any method known to us. For example, chalk may by heat be decomposed into two substances, one a colorless gas, called carbon dioxid; the other a white powder, called calcium oxid, or, commonly, lime. These products are different from the chalk and from each other, but they do not represent the limit of decomposition, for by special methods each can be made to yield two substances. The lime yields a solid (called calcium) and a gas called oxygen; the carbon dioxid yields a solid (called carbon) and a gas which is the same as that from the lime, namely, oxygen. The substances obtained in this second step are incapable of further decomposition by any known process. By proceeding in this way with all known substances, chemists have determined the limits of decomposition, and have established that all material objects may be regarded as formed from a limited number of undecomposable substances. These are called *elements*. So far as at present known these elements are entirely independent forms, and are incapable of conversion into one another.

About eighty elements are now known, and the number is from time to time increased by the discovery of new ones. Every substance known to us is either one of these elements or a combination of two or more of them. Consequently all bodies are divided into two classes, *elementary* and *compound*. The main object of chemistry is to discover what elements are present in any body and what are the laws governing the action of the elements upon each other.

Analysis and Synthesis.—When the composition of a body is determined by separating the elements contained in it, the process is called *analysis;* when bodies are produced by combining elements the process is called *synthesis*.

Nature of the Elements.—A table of all the elements at present definitely known will be found at the end of the book. For the purpose of preliminary study it will be necessary to enumerate only a few, as many of the elements occur only in rare substances. For scientific purposes they are usually arranged in groups in which those bearing the closest resemblance are brought together. The following table is a provisional grouping of the important elements, and the student will find it advantageous to commit these to memory, as the arrangement will aid in future study.

Oxygen Group.	*Chlorin Group.*	*Nitrogen Group.*	*Carbon Group.*
Oxygen,	Chlorin,	Boron,	Carbon,
Sulfur,	Bromin,	Nitrogen,	Silicon,
Selenium,	Iodin,	Phosphorus,	Tin,
Tellurium.	Fluorin.	Arsenum,	Platinum.
– II	– I	Antimony,	+ III
		Bismuth,	
		Gold.	

only element to form ~~[illegible]~~ [illegible] with of O group

Generally – III or V

affinity for
O and Cl
group.

Potassium Group.
Potassium,
Sodium,
Lithium,
Hydrogen,
Silver.
+ I

Calcium Group.
Calcium,
Barium,
Strontium,
Lead.
+ II

Zinc Group.
Zinc,
Magnesium,
Cadmium.
+ II

Iron Group.
Iron,
Manganese,
Aluminum,
Chromium,
Nickel,
Cobalt.
+ II or triple III

Copper Group.
Copper.
Mercury.
+ II

Recent observations on certain rare elements have indicated a possibility of breaking them into simpler forms, and it appears probable that in a few years our views as to the nature of the elements will undergo change.

Atomic Theory.—We may reduce any solid, a piece of sulfur, for instance, to powder, and it would seem as if no limit existed to such division. Chemists, however, are now generally of the opinion that a limit does exist, and that every substance is made up of particles of definite size and incapable of further division. Such particles are very small, and equally hard, no matter what the nature of the mass which they constitute. They are called ATOMS (a word signifying indivisible); any mass of elementary matter consists of a collection of a greater or less number of these atoms. It is believed that the atoms are rarely, if ever, perfectly free, but associated in groups, called MOLECULES. When, therefore, we powder the sulfur, we merely separate the molecules from each other.

Molecules consisting of one kind of atoms are called *elemental* molecules; those containing more than one kind are called *compound* molecules.

Atoms and molecules are believed to be in a constant state of vibration, the rapidity of which increases with increase of temperature, and is, therefore, more rapid in the liquid than in the solid state, and still more rapid in the gaseous condition. This is known as the *kinetic theory.*

When a solid becomes a liquid or a liquid becomes a gas, or the reverse occurs, the molecules are not changed, but merely separated from one another. Hence the atoms in sulfur vapor are as hard and solid as those of solid sulfur, but in the vapor the molecules which they form are separated by greater distances than in the case of the solid.

The force which holds *atoms* together and forms them into molecules is a chemical force, and is called CHEMICAL AFFINITY. Any number of *molecules* of the same kind may be held together in a mass; the force that does this is called COHESION.

As yet only the relative atomic weights of the elements have been determined by chemical researches; in these the hydrogen atoms, as they possess the least weight, have been taken as unity. Until now the knowledge of the absolute atomic weight for chemical considerations has been unessential. At the present time different physical phenomena permit fixing the absolute size of the atom with considerable accuracy (Richter). Very different considerations lead to the same conclusion, that the atoms cannot be smaller than the fifty-millionth part of a millimeter (Thomson). Loschmidt gives the diameter of a molecule of hydrogen at 0.0000004 of a millimeter. The atomic theory was known to some of the Greek philosophers. One of them describes the nature of matter in terms resembling those used in modern works.

Atomic Weights.—Chemists have never been able to isolate or render visible atoms or molecules. Nevertheless, the progress of chemical research has developed some general principles.

1st. That the atoms of each element have a constant and definite weight.

2d. That the atom of hydrogen is the lightest of all.

3d. That combination takes place among atoms under the action of chemical affinity.

Starting with the first two principles numbers have been obtained which are supposed to represent the weight of each atom compared to the atom of hydrogen. These numbers are called ATOMIC WEIGHTS.

In any compound the sum of all the atomic weights is called the *molecular* weight. Thus, sulfuric acid is H_2SO_4; its molecular weight is 98.

$$\begin{aligned} H_2 &= 2\ (2 \times 1) \\ S &= 32 \\ O_4 &= \underline{64}\ (16 \times 4) \\ & \quad 98 \end{aligned}$$

NOTATION.

In chemistry, a *symbol* is an abbreviation of the name of an element; in most cases an initial letter is used, as C for carbon, P for phosphorus. Since some elements have names beginning with the same letter, proper distinction is obtained by assigning the single letter to the most common, and attaching small letters to the other initials. Thus, C stands for carbon, Ca for Calcium, Cl for chlorine, Cd for cadmium. Some elements have different names in different languages, and for these the symbol is formed from the Latin name. Iron, for instance, is represented by Fe (*ferrum*); lead by Pb (*plumbum*); silver by Ag (*argentum*); potassium by K (*kalium*).

To express combination between elements—in other words, to express the composition of a compound body or of a molecule—the symbols are to be written together like the letters of a word. Such a collection of symbols is called a FORMULA.

The symbol, however, not only represents the element, but one atom of it. The expression CaO not only shows a compound consisting of calcium and oxygen, but also indicates that it contains a single atom of each element. CaO_2 shows that two atoms of oxygen are present and one of calcium. In writing these expressions certain rules are followed :—

1st. To multiply any single atom, a small number is attached to the lower right hand, as seen above, where O_2 indicates two of oxygen. The formula $C_2H_4O_2$ shows a combination consisting of two atoms of carbon, four of hydrogen and two of oxygen.

2d. To multiply several atoms by the same number, we put a large figure in front. Thus $2HClO$ is equal to $H_2Cl_2O_2$; that is, the large figure multiplies the whole expression.

3d. To multiply a portion of an expression, several methods are in use. We may enclose the part to be multiplied in parentheses, and attach the proper number to the right-hand corner. $Ba(NO_3)_2$, for instance, equals BaN_2O_6; $C_6H_8(NO_2)_2O_5$ equals $C_6H_8N_2O_9$, The effect of the small figure is limited to the part within the parentheses. This method is especially adapted to multiplying symbols in the middle or at the end of a formula. To multiply the symbols at the beginning of a formula, we usually point off or punctuate the part to be affected, and place a large figure in front. Some irregularity prevails as to the particular sign used, the comma and semicolon both being employed. It is sufficient for the student to bear in mind that a punctuation mark or plus sign occurring in a formula will stop the multiplying effect of the large figure at the beginning of the expression. For instance, $2C_2H_5,H_2N$, is equal to $C_4H_{10}H_2N$; similarly, in $2FeSO_4 + HCl$ the letters following the plus sign are not affected by the figure 2. If we wish to carry the multiplying effect to the end of the expression, we enclose it in parentheses; thus, $2(FeSO_4 + HCl)$. Here all the letters are equally influenced.

Since the symbol of each element represents one atom, it follows that every symbol carries with it an idea of quantity. If we write HCl, the meaning is not merely that hydrogen and chlorin are in combination, but that the amounts by weight are in the proportion of the atomic weights; *i.e.*, 1 (atomic weight H) to 35.4 (atomic weight Cl). When the symbol is multiplied, the weight is also multiplied. For instance, H_2O represents 2 parts by weight of H to 16 of O; $HgCl_2$ represents 200 parts of mercury and 70.8 (35.4×2) parts of chlorin.

NOMENCLATURE.

The names of chemical compounds are regulated by a system which depends essentially upon the employment of certain terminations.

In the old division of the elements into metals and non-metals, the metals were usually distinguished by the termination "*um.*" A change of this termination into "*a*" indicated combination with oxygen. Potassium (K) becomes by oxidation, potassa (K_2O); sodium (Na) becomes soda (Na_2O); magnesium (Mg) becomes magnesia (MgO). As the name of many of the common metals, do not end in "um" unless the Latin name is used, this rule is only of limited application. The tendency of the modern nomenclature is to make but little change in names ending in "um."

Chemical compounds which contain only two elements are called *binary compounds.* They are usually named by joining the names of the elements present and attaching to one of them the termination "*id.*" This termination may be conveniently regarded as an equivalent of the phrase "nothing else;" that is, wherever it occurs it indicates that nothing else is present except what is expressly mentioned. Potassium iod*id*, for instance, can contain nothing else but potassium and iodin; copper sulf*id* can contain nothing but copper and sulfur.

PbO . . . . Lead ox*id*.
NaCl . . . . Sodium chlor*id*.
AgBr . . . . Silver brom*id*.

The syllable "id" is usually attached to the members of the oxygen, chlorin, nitrogen and carbon groups, and preferably to those of the first two groups. Thus, a compound of iron and carbon is called iron carbid, but a compound of carbon and chlorin is called carbon chlorid.

In many books, especially in older works, the word "of" will be found frequently used in the names of compounds. Instead of copper nitrate, we see nitrate of copper, iodid of potassium for potassium iodid.

As elements may combine in several proportions, forming several different compounds, this termination *id* does not suffice. The bodies Cu_2O and CuO are both properly called copper oxid, because they contain only copper and oxygen, but they are different. In the same way, SO_2 and SO_3 are both sulfur oxids. The distinction is made by prefixes,

Cu_2O . . . Copper *sub*oxid.
CuO . . . " *mono*xid (formerly *proto* was used).
SO_2 . . . Sulfur *di*oxid (formerly *deut* or *bin* was used.
SO_3 . . . " *tri*oxid (also *ter*oxid).
CCl_4 . . . Carbon tetrachlorid or quadrichlorid.
PCl_5 . . . Phosphorus pentachlorid.

Sub generally indicates deficiency; that is, that the quantity of the element to which it is attached is less than it should be. We apply the term *sub* especially to compounds in which a member of the oxygen or chlorin group is deficient in amount. Pb_2Cl, Zn_3I_2, Cu_2O would be sub-compounds.

Some elements form compounds in which the proportion is as 1 to 1½, but as fractions are not allowed in formulæ, the whole expression is multiplied by 2, which gives the proportion 2 to 3. FeO1½ becomes, therefore, Fe_2O_3. These are called *sesqui* compounds. Fe_2O_3 is iron sesquioxid. The word *sesqui* means one and a half, and conveys the idea that the relation between the two elements is as 1 to 1½ (2 to 3).

There is no uniform method for giving names to compounds containing more than two elements. Sometimes the system is the same as that just given; all the elements are mentioned and the termination "id" is attached. Thus KHO is potassium hydroxid, NaHO is sodium hydroxid. In other cases a portion of the compound is included under a group name, and this is joined with the names of the other elements according to the above rule. Thus KCN is not called potassium carbonitrid, but the CN is called cyanogen, and the entire compound is called potassium cyanid.

Among the compounds containing three elements are those which we call *salts*. If we put zinc or zinc oxid into sulfuric acid, we get a zinc salt; in this case zinc sulfate: also by direct union of many oxids; for instance, when calcium oxid, CaO, acts upon carbon dioxid, CO_2, we get calcium carbonate, $CaCO_3$, which is a salt.

Most salts contain *three* elements, of which *oxygen* is one, and the names are made by joining the names of the other two elements and adding to them certain syllables which not only indicate the presence of oxygen, but also partly the amount. These syllables are *ate* and *ite*. The former indicates the greater quantity of oxygen. The potassium sulf*ate* and potassium sulf*ite* both contain oxygen, but the former (sulf*ate*) contains the more oxygen. Sodium nitr*ate* and sodium nitr*ite* contain the same elements, but their composition is $NaNO_3$ and $NaNO_2$, respectively.

It has been pointed out that the syllable *id* could be regarded as equivalent to the phrase "nothing else." In the same manner, the syllables *ate* and *ite* may be regarded as meaning "something else," generally oxygen. Thus, while in sodium sulf*id* but two elements are present, sodium sulf*ate* and sulf*ite* will contain three.

These two terminations are not sufficient. Potassium, chlorin and oxygen unite in four different proportions, forming $KClO_4$, $KClO_3$, $KClO_2$, KClO. In such cases the important or most common compound is distinguished by the termination *ate*, and the one containing the next lower amount of oxygen by the termination *ite*.

The other compounds are indicated by the use of certain extra syllables, *hypo* and *hyper*, the latter now generally abbreviated to "per." The significance and use of these syllables are shown in the following table :—

$KClO_4$	Potassium perchlorate,
$KClO_3$	" chlorate.
$KClO_2$	" chlorite.
$KClO$	" hypochlorite.
Na_2SO_4	Sodium sulfate.
Na_2SO_3	" sulfite.
Na_2SO_2	" hyposulfite.

When hydrogen is present in such compounds, a different method is adopted.

Thus we have $HClO_4$, $HClO_3$, $HClO_2$, $HClO$, and these might be called hydrogen perchlorate, hydrogen chlorate, etc. The usual method is to drop the word hydrogen, change the termination *ate* into *ic*, the termination *ite* into *ous*, and add the word acid,

$HClO_4$	Perchlor*ic* acid.
$HClO_3$	Chlor*ic* acid.
$HClO_2$	Chlor*ous* acid.
$HClO$	Hypochlor*ous* acid.

The *prefixes* are retained without change, and the syllable *ic* corresponds to *ate*, and the syllable *ous* to *ite*.

Potassium sulfate K_2SO_4	corresponds to	Sulfuric acid H_2SO_4
Potassium sulfite K_2SO_3	"	Sulfurous acid H_2SO_3
Potassium hyposulfite K_2SO_2	"	Hyposulfurous acid H_2SO_2

Sometimes the hydrogen is only partly replaced by another element, and the body intermediate between the acids and the salts. Thus $KHSO_4$, is at once a potassium and a hydrogen compound. It is called acid potassium sulfate. The word *acid* calls attention to the hydrogen. These acid salts are not unfrequently called *bi*-salts. Acid potassium sulfate is known in commerce as potassium bisulfate ; the corresponding acid carbonate, $KHCO_3$, as bicarbonate. The use of the syllable *bi* is improper. In a few cases "*bi*" is used where "di" is now preferred.

The terminations "ous" and "ic" are employed with elements forming two sets of compounds.

Iron forms two chlorids, two iodids, two sulfids, etc., as follows:—

FeO	$FeCl_2$	$FeSO_4$	Ferr*ous* salts.
Fe_2O_3	Fe_2Cl_6	$Fe_2(SO_4)_3$	Ferr*ic* "

These terminations do not indicate the amount of the element to which they are attached, but of the other substance; *ous*, as usual, means less than *ic*.

LAWS OF COMBINATION.

The great law of chemistry is the law of *constant proportion*. Each chemical compound is definite in its nature, the proportion of its constituents being constant. Water, for instance, when pure, always consists of 11.11 per cent. of hydrogen and 88.89 per cent. of oxygen.

Elements, however, are not limited to one proportion of combination, but in each proportion a different body is produced. Thus, there is a compound containing about six per cent. of hydrogen and ninety-four per cent. of oxygen. It is, however, very different from water. So, also, there are five compounds of nitrogen and oxygen, all different bodies. When the proportions present in different compounds are expressed in terms of atomic weight, it is generally found that a simple multiple relation exists. For instance, the two compounds of hydrogen and oxygen have the formula, respectively.

H_2O . . . . . . Water.
H_2O_2 . . . . . . Hydrogen dioxid.

The five compounds of nitrogen and oxygen are N_2O, NO, N_2O_3, NO_2, N_2O_5.

The fact has given rise to a second law, or rather rule, called the law of multiple proportion, viz., When elements combine in more than one proportion, the higher proportions are simple multiples of the lower.

The same simplicity and constancy of proportion is observed in the combination of compound bodies. The combining weight of a compound body equals the sum of the atomic weights of its constituents. Thus, lime consists of calcium and oxygen—CaO. The combining weight is $Ca = 40\ O = 16 \therefore CaO = 56$. When lime is mixed with water the two bodies combine in definite proportions. $H_2 = 2\ O = 16 \therefore H_2O = 18$. 56 and 18 are respectively the molecular weights of lime and water, and it is in this proportion they combine; 56 parts by weight of lime with 18 parts by weight of water, forming 74 parts of slacked lime—

$$CaO + H_2O = CaH_2O_2.$$

VALENCY.

Elements, as above noted, may combine in several proportions. When compounds containing the same elements are compared, we generally find one proportion which seems to be the most natural; it is either most frequently or easily produced, or it is the one least liable to change. Hydrogen and oxygen combine in two proportions, thus:—

$$\left.\begin{array}{l} 2 \text{ parts by weight H} \\ 16 \text{ `` `` `` O} \end{array}\right\} = H_2O. \quad \text{Hydrogen monoxid.}$$

$$\left.\begin{array}{l} 2 \text{ parts by weight H} \\ 32 \text{ `` `` `` O} \end{array}\right\} = H_2O_2. \quad \text{Hydrogen dioxid.}$$

These bodies are very different. The first is *water*, a compound not liable to decompose. The second substance is difficult to prepare and to preserve; it is liable to explode. We may suppose, therefore, that the normal proportion of combination between H and O is H_2O. Carbon forms with oxygen two well marked compounds, CO and CO_2. CO is formed when carbon is burned in a *deficient* supply of oxygen, but CO_2 is formed when the carbon burns under natural conditions in a free draft of air or oxygen. CO, besides, shows a tendency to take up more oxygen, especially when heated, and it will combine with chlorin, even at ordinary temperatures. CO_2, on the other hand, shows no tendency to combine with either oxygen or chlorin.

The atom of hydrogen has been taken as a point of comparison, and each element compared according to the number of hydrogen atoms with which it forms the most permanent combination. For instance, we find compounds with hydrogen as follows:—

Cl	combines	with one	H,	forming	HCl.
Br	"	" "	H,	"	HBr.
O	"	" two	H,	"	H_2O.
S	"	" "	H,	"	H_2S.
N	"	" three	H,	"	H_3N.
As	"	" "	H,	"	H_3As.
C	"	" four	H,	"	H_4C.

These are not the only compounds that can be formed from these elements, but they are those which show only a slight tendency either to take new atoms or give up what they already possess.

The number of hydrogen atoms with which any element combines is called *its VALENCY.* The term *atomicity* was formerly used, but is not now much employed. Degrees of valency are indicated by names and Roman numerals, the latter being placed to the upper right hand of the symbol.

I indicates a monad (monatomic or monovalent).
II " a dyad (diatomic or bivalent).
III " a triad (triatomic or trivalent).
IV " a tetrad (tetratomic or tetravalent).
V " a pentad (pentatomic or pentivalent)
VI " a hexad (hexatomic or hexivalent).
VII " a heptad (heptatomic or heptivalent).

Valency has nothing to do with the energy or activity of the element. It is a measure of capacity only. Bodies of high valency are often of weak affinity, while some of the strongest chemical agents are of low valency. Chlorin has ordinarily only one-third the valency of nitrogen, but it is much more active when free.

Degrees of valency are determined by a study of the proportions in which bodies combine; a knowledge of the valency of the elements is a key to the composition of all their important and more permanent compounds. The following gives the valency of the principal groups of elements:—

Monad,—potassium and chlorin groups.
Dyad,—oxygen, iron, calcium, zinc groups, and frequently the iron group.
Triad and pentad,—nitrogen group.
Tetrad,—carbon group and sometimes the iron group.

When elements are combined in such proportions that their valencies are equalized, the compounds are said to be *saturated*. This meaning must be distinguished from the more common one, viz., that a body has dissolved or absorbed as much of any substance as it can take up. In this latter sense we speak of *saturated solutions*, meaning solutions which contain as much of any substance as can be dissolved.

Taking the monad group, for instance, the members being equal to one atom of H, they are equal to each other. Hence, K and Cl will combine in equal number of atoms, forming KCl, potassium chlorid. Similarly we will have NaBr, AgI, etc. The dyad elements have twice the combining capacity of monads; we will find, therefore, that the compound of sodium and oxygen will be Na_2O.

The combination between triad antimony and chlorin will be $SbCl_3$; between tetrad carbon and dyad oxygen will be CO_2; between pentad nitrogen and dyad oxygen N_2O_5.

The degrees of valency given above are not invariable. The circumstances under which the variation takes place cannot be very well defined; but the extent or rate of variation is by a simple law, to which only a few exceptions need be made. *When an element changes its valency, either increasing or diminishing, the change is by two degrees at a time.* Elements of even valency remain even, passing, for instance, from hexads to tetrads, and finally to dyads, or the reverse; elements of uneven valency remain uneven, passing from pentads to triads and monads, and the reverse.

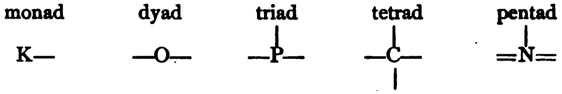
Certain elements seem to be exceptional, but, by a supposition, we preserve the application of the law. These bodies are supposed to have the property of combining with themselves in such a manner as to form double atoms, possessing a valency greater than either atom singly, but less than the sum of the valencies of the two atoms. Iron, generally a dyad, becomes in certain compounds a tetrad, but two atoms of iron unite and form a double atom, which then forms compounds with other elements. A short reflection will show that this double atom, formed from two atoms each having a capacity of four, will have a power of six, one degree of valency in each atom being saturated.

For cases of varying valency, the terminations *ous* and *ic* are employed, *ous* indicating the lower degree and *ic* the higher. We have in this way manganous (lower valency) and manganic (higher valency) salts, ferrous (dyad) and ferric (hexad) compounds. In the terminations of the names of acids the same principle is carried out, sulfurous acid being the compound in which sulfur has a lower (tetrad) valency; sulfuric acid one in which sulfur has a higher (hexad) power.

We not only employ a knowledge of valency for determining the proportion of combinations between any two elements, but starting with any molecule, we may by substitution obtain the formula of any derivative of that molecule. Thus the body called nitric acid, forms derivatives called nitrates, in which the hydrogen of the acid is replaced by other positives. Suppose we wish to write the formula of potassium nitrate; the reasoning would be as follows: Nitric acid is HNO_3—potassium is a monad; one atom of potassium will substitute the atom of hydrogen, and the formula is KNO_3. By the same reasoning the formula of copper sulfate may be deduced. Sulfuric acid is H_2SO_4, copper is a dyad; one atom of copper will displace two of hydrogen; therefore, $CuSO_4$. When the standard formula contains too small an amount of hydrogen, we must multiply the expression by some whole number. For instance, the formula of copper nitrate will be deduced in this manner: Nitric acid is HNO_3, copper is a dyad; copper will therefore replace the hydrogen *of two molecules of nitric acid;* hence, $Cu(NO_3)_2$ or CuN_2O_6.

If we take one or more atoms from a saturated compound, we leave the compound unsaturated to a degree equal to the hydrogen atoms to which the removed atoms correspond. The molecule H_4C is saturated. The molecule H_3C can take up one H or its equivalent, and is therefore a monad; H_2C can take up H_2, and is therefore a dyad; and so on. The valency of any molecule can thus be obtained by finding how much hydrogen is required to form a saturated compound. By this method we determine that HO is a monad, for it requires but one atom of H to complete the molecule; CO_3 is a dyad, for it requires H_2 to form the saturated compound H_2CO_3; PO_4 is a triad, for it forms H_3PO_4. (See section on Radicles.)

Graphic Formulæ.—A convenient and much used method of indicating valencies is by *graphic formulæ.* These consist of the symbol of each element, with bonds or prolongations the same in number as the degrees of valency. Taking some common elements as examples, we have



$$\text{K—} \qquad \text{—O—} \qquad \overset{|}{\text{—P—}} \qquad \underset{|}{\overset{|}{\text{—C—}}} \qquad \overset{|}{\text{=N=}}$$

These bonds may be attached in any position or direction as long as the proper number is used. Carbon, for instance, may be written as above, or

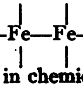
$$C\equiv \qquad —C= \qquad =C= \qquad \equiv C$$

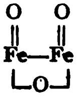
or in any other way, provided four bonds are present.

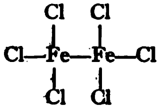
In the practical application of this notation we link together the bonds of the different elements, and when all the points are joined the compound is complete, and is a saturated molecule. Two bonds of one atom, however, can never be attached to a single bond of another atom. The following are examples of some common compounds written graphically:—

$$\text{H—Cl}; \qquad \text{H—O—H}; \qquad \text{H—N}\genfrac{}{}{0pt}{}{\text{—H}}{\text{—H}};$$
$$O=C=O.$$

We may also indicate *unsaturated* molecules. Thus, $O=C=$ shows that carbon monoxid is a body having two degrees of valency unsatisfied; $O=C=\genfrac{}{}{0pt}{}{Cl}{Cl}$ that two atoms of chlorin have combined and satisfied this free valency.

The nature of the change by which the iron atom passes from a dyad to a hexad condition can be very well shown by this method. Dyad iron, graphically represented, would be $Fe=$, in which two bonds have disappeared, leaving two still active. In the higher degree of valency (tetrad) the condition is  $-\overset{|}{\underset{|}{Fe}}-\overset{|}{\underset{|}{Fe}}-$, one bond of each atom having combined and linked the two in chemical union. Ferric oxid and ferric chlorid would be





ELECTRICAL RELATIONS OF THE ELEMENTS.

Electrical excitement exhibits two conditions, called respectively *positive* and *negative*, which are produced in any apparatus developing electricity. The points at which the electrical excitement is manifested—for instance, the ends of the wires of a battery—are called the poles. The positive pole, also called the *anode*, is distinguished by the sign, +, and the negative, also called the *kathode*, by the sign —.

Two bodies differently electrified will attract each other, but if charged with the same kind of electricity will repel. The law is generally expressed as follows: *Like electricities repel; unlike attract.*

These principles have been applied to the determination of some important relations between elements. A current of electricity decomposes many compound bodies; some elements appearing at the positive pole, and others at the negative. Thus, potassium will be liberated in contact with the surface negatively charged, and oxygen in contact with the positive surface. This will be the invariable result with these elements, no matter what compounds be taken for the experiment, but with many other elements the effect will depend upon the nature of the compound. With H_2S the sulfur will appear at the positive pole; with SO_2, at the negative.

Since unlike electricities attract, it follows that elements which go to the positive side must be negative, and those at the negative side must be positive. Very frequently we use the term "ELECTRO" in this connection; thus we say, zinc is *electro-positive;* chlorine is *electro-negative.*

A body is not absolutely positive nor absolutely negative, but is simply more positive or more negative than some other substance. Nevertheless, as the list of elements is limited, we will have two bodies which, by their high affinities, will stand at the extremes of the scale, one being negative, the other positive. Leaving out of consideration some rare elements, we may place potassium as the most positive, oxygen as the most negative.

The applications of the above principles will be presented in connection with the discussion of Radicles and Reactions.

REACTIONS.

Chemical symbols are employed not only to show the composition of bodies, but also to show exactly the nature of the chemical changes which occur when different bodies are brought in contact. When so used, the expression is called a REACTION. Strictly speaking the statement in symbols is the "equation of the reaction," but the shorter term is generally used. Certain compounds, which are much used for producing reactions, are called REAGENTS, though strictly all the substances present take equal part in a reaction. When we pour vinegar upon a marble table, we say, in ordinary phrase, that the marble is corroded, but, in fact, the vinegar is equally acted upon, both substances are changed in composition, both are rendered unfit for their original uses; in other words they have not only acted, they have reacted, and are therefore both reagents.

A reaction is substantially an expression of the results of an experiment, and, when correctly written, gives us the proportion in which bodies are to be used and the proportion of the resulting substances. Speaking absolutely, we can never be sure of the correctness of any reaction until we make the experiment and analyze the result; but the progress of chemistry has made known certain laws of change, which enable us to predict, or infer, many results without the necessity of actual observation. Every now and then, however, the analogy fails, and experiment disappoints the suggestions of theory.

Reactions are written by placing in proper proportion and connected by + signs the formulæ of the bodies concerned, then writing the sign = and following this by the formulæ of the resulting bodies. For instance,

$$AgNO_3 + HCl = AgCl + HNO_3$$

expresses that on bringing together silver nitrate and hydrochloric acid, a chemical change occurs by which silver chlorid and nitric acid are produced. Students find, in regard to writing reactions, three difficulties: 1st. To know whether a given change will take place. 2d. To know the quantities of the bodies to be used. 3d. To know the nature of the resulting bodies. These difficulties may be taken up in order. 1st. In the simplest cases, the nature of the reaction will be determined by the affinities of the elements as governed by their electrical relations, the change taking place in such a way that the element having the stronger electric affinity will drive out and supplant the element of similar but weaker affinity. We find that when chlorin acts upon the bromids they are decomposed, the bromin being expelled, and that bromin, in turn, expels iodin from combination. Therefore, such reactions as

$$\begin{aligned} KBr + Cl &= KCl + Br \\ KI + Br &= KBr + I, \end{aligned}$$

are simply illustrations of the general electrical relations of elements concerned. If these affinities were the only active causes of chemical change, the subject would be quite simple, but circumstances may modify the play of affinities, so as to produce an endless variety of chemical action. All the modifying influences are not yet known, but some of them are understood, and are of importance.

(*a*) **Insolubility.**—When in any liquid we bring together substances which are capable of forming a body insoluble in the liquid, that insoluble compound will be produced in spite of the general relations of affinities. This influence of insolubility is the basis of a large number of tests and other chemical operations.

When the formation of the insoluble compound would require a powerful chemical agent to be set free, the change will not take place, unless, of course, the added substance is stronger than the one to be liberated. Carbonic acid forms with calcium a body quite insoluble in water, but this body cannot be formed by passing carbonic acid into calcium sulfate. The reason is shown at once by examining the conditions of the experiment. The reaction would have to be $CaSO_4 + H_2CO_3 = CaCO_3$ (insoluble) $+ H_2SO_4$, that is, sulfuric acid would be set free. The activity of H_2CO_3 is, under ordinary conditions, so much below that of H_2SO_4 that the former will not drive out the latter. The condition becomes changed if we assist the action of the carbonic acid by some substance which has an affinity for sulfuric acid and will prevent it being set free. $CaSO_4 + Na_2CO_3$ will produce immediate action, resulting in $CaCO_3 + Na_2SO_4$. This reaction illustrates a common method of keeping the powerful affinities in abeyance, and thus allowing secondary influences full play. Some of the arsenic tests show the principle strikingly. Arsenous acid added to copper sulfate produces no action, because the affinity of the SO_4 is too strong, but by adding a little alkali, the strong affinity this has for SO_4 assists in breaking up the copper sulfate and immediately a precipitate of copper arsenite falls.

(*b*) **Volatility.**—This is the second influence that disturbs ordinary affinities. If a body is capable of being converted into a gas, this fact will diminish its chemical power; fixed substances that have ordinarily less affinity will drive it out of combination. Boric acid, for instance, is one of the weak acids, yet at a red heat it will drive out even sulfuric acid. The cause is, in the main, that at this temperature sulfuric acid is volatile, while boric acid is fixed.

The ease with which hydrogen is driven out of combination may be regarded as due to its volatility, being a gas even at low temperatures.

(*c*) **Mass.**—Sometimes chemical action seems to be governed by the quantity of the substance present. If we pass water vapor over red-hot iron, iron oxid is formed and hydrogen is set free; if we pass the hydrogen back over the iron oxid, steam is formed and iron set free. In the first case, the water is in excess, and exerts an oxidizing influence; in the second, the hydrogen is in excess, and exerts a deoxidizing influence. The effect of mass is indefinite and uncertain, and need not enter into the ordinary working of reactions.

It will be seen to be a deduction from these statements that no substance can be set down as absolutely the strongest in affinity. Chemists cannot determine, for instance, what is the strongest acid or the strongest alkali, except under specified conditions.

2d. The proportion in which bodies react is determined by their valencies. Let it be required to write the reaction between mercuric chlorid and potassium iodid. The formulæ are $HgCl_2$ and KI, but the bodies will not react in this proportion, for the Hg will require I_2 and Cl_2 will require K_2. The proper reaction is $HgCl_2 + 2KI = HgI_2 + 2KCl$. In the same way, antimonous sulphid and hydrochloric acid can only act upon each other in the ratio $Sb_2S_3 + 6HCl$ because Sb being a triad, Sb_2 will combine with Cl_6, and S being a dyad, S_3 will require H_6.

3d. If a chemical change occurs when two given substances are brought in contact, the nature of it will depend principally upon the electrical relations of the elements concerned. In the reaction $HgCl_2 + H_2S$, the only possible result is the combination of S with Hg and H with Cl, as is shown at once by placing the proper signs over the elements, $\overset{+}{Hg}\,\overset{-}{Cl_2}$ $\overset{+}{H_2}\,\overset{-}{S}$. Such a combination as $\overset{+}{Hg}\,\overset{+}{H_2}$ or $\overset{-}{Cl_2}\,\overset{-}{S}$ could not take place, since it requires like electricities to attract, which is against the rule. In beginning with reactions, the student will do well to place the proper signs over each element, and these will be a useful guide and control. When acids or salts, containing three elements, are part of the reaction, the positive sign is put over the hydrogen or the metal, and the negative sign over the oxygen and other element, thus:—

$$\overset{+}{Ba}\overset{-}{(NO_3)_2} + \overset{+}{K_2}\overset{-}{SO_4} = \overset{+}{Ba}\overset{-}{SO_4} + 2\overset{+}{K}\overset{-}{NO_3}.$$

The placing of the single sign over two elements is simply an evidence of the fact that in ordinary reactions these two elements act as a single element.

The following formulæ will further illustrate the general principle:—

$$\overset{+}{\mathrm{Ag}}\,\overset{-}{\mathrm{NO_3}} + \overset{+}{\mathrm{Na}}\,\overset{-}{\mathrm{Cl}} = \overset{+}{\mathrm{Ag}}\,\overset{-}{\mathrm{Cl}} + \overset{+}{\mathrm{Na}}\,\overset{-}{\mathrm{NO_3}}$$

$$\overset{+}{\mathrm{H_2}}\,\overset{-}{\mathrm{O}} + \overset{-}{\mathrm{Cl_2}} = 2\overset{+}{\mathrm{H}}\,\overset{-}{\mathrm{Cl}} + \overset{-}{\mathrm{O}}$$

$$\overset{+}{\mathrm{Ba}}\,\overset{-}{\mathrm{Cl_2}} + \overset{+}{\mathrm{K}}\,\overset{+}{\mathrm{H}}\,\overset{-}{\mathrm{SO_4}} = \overset{+}{\mathrm{Ba}}\,\overset{-}{\mathrm{SO_4}} + \overset{+}{\mathrm{K}}\,\overset{-}{\mathrm{Cl}} + \overset{+}{\mathrm{H}}\,\overset{-}{\mathrm{Cl}}$$

In the last reaction, the electro-positives K and H may seem to be in union, but this is not the case. Each is independently united to the SO_4, which is a dyad. The formula might be written—

$$\begin{matrix}\mathrm{K}\\ \mathrm{H}\end{matrix}\mathrm{SO_4}.$$

RADICLES.

A radicle is any group of atoms having unsatisfied valency, the number of these unsatisfied degrees being the valency of the radicle. The following formulæ illustrate the principle. The degrees outside the parentheses indicate in each case the valency of the radicle, being, of course, the difference between the valencies of the constituent atoms:—

$$(\overset{\mathrm{V}}{\mathrm{N}}\overset{\mathrm{II}}{\mathrm{O}}_3)^{\mathrm{I}} \quad (\overset{\mathrm{V}}{\mathrm{N}}\overset{\mathrm{II}}{\mathrm{O}}_2)^{\mathrm{I}} \quad (\overset{\mathrm{IV}}{\mathrm{C}}\overset{\mathrm{III}}{\mathrm{N}})^{\mathrm{I}} \quad (\overset{\mathrm{IV}}{\mathrm{C}}\overset{\mathrm{II}}{\mathrm{O}})^{\mathrm{II}} \quad (\overset{\mathrm{I}}{\mathrm{H}}\overset{\mathrm{II}}{\mathrm{O}})^{\mathrm{I}} \quad (\overset{\mathrm{I}}{\mathrm{H}}\overset{\mathrm{IV}}{\mathrm{C}})^{\mathrm{III}}$$

The electrical relations of a radicle are generally determined by the electrical character of the preponderating valency, but not invariably. While the combining capacity and general functions are subsequently dependent on the unsaturated valency, yet, in chemical combinations, the whole molecule takes part, and hence the electrical character is influenced by that of each atom present. Thus in $(\overset{\mathrm{V}}{\mathrm{N}}\overset{\mathrm{I}}{\mathrm{H}}_4)^{\mathrm{I}}$ we might infer that the nitrogen valency would only give to the radicle indifferent or intermediate electrical relations, but experiment shows that this is a group having distinctly positive affinities: the four atoms of positive hydrogen, though insufficient to saturate all of the nitrogen valency, yet impress on the molecule their function.

In many cases the influence of the preponderating valency is more decided. Thus in $(\overset{\mathrm{V}}{\mathrm{N}}\overset{\mathrm{II}}{\mathrm{O}}_3)$ the oxygen valency is in excess, and the radicle is negative.

The compounds of carbon show very well the principle on which the valency of a radicle depends:—

$H_4\overset{\text{IV}}{C}$	Saturated.
H_3C	Monad.
H_2C	Dyad.
$H\ C$	Triad.
C	Tetrad.

The last is the free element which might be regarded as the final radicle, so that we may speak of both elemental and compound radicles, but the term is usually limited to the latter signification.

The following formulæ give the compositions, valencies and names of some important radicles :—

$\overset{\text{V}}{N}\overset{\text{I}}{H}_4$	Ammonium	Monad.
$\overset{\text{III}}{N}\overset{\text{I}}{H}_2$	Amidogen	“
$\overset{\text{I}}{H}\overset{\text{II}}{O}$	Hydroxyl	“
$\overset{\text{I}}{H}\overset{\text{II}}{S}$	Hydrosulfyl	“
$\overset{\text{IV}}{C}\overset{\text{III}}{N}$	Cyanogen	“
$\overset{\text{I}}{H}_3\overset{\text{IV}}{C}$	Methyl	“
$\overset{\text{V}}{N}\overset{\text{II}}{O}_2$	Nitrosyl	“
$\overset{\text{IV}}{C}\overset{\text{II}}{O}$	Carbonyl	Dyad.

ACIDS, BASES AND SALTS.

Acids are compounds in which hydrogen is united directly either to strongly negative elements, or to positive elements, which are at the same time united to some member of the oxygen group. Several classes of acids may, therefore, be distinguished.

Hydrogen acids—commonly called hydro-acids—

HCl	Hydrochloric acid.
HBr	Hydrobromic acid.
HI	Hydriodic acid.
HF	Hydrofluoric acid.

Oxygen acids—

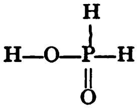
H_2SO_4	Sulfuric acid.
HNO_3	Nitric acid.
H_3PO_4	Phosphoric acid.
H_2CO_3	Carbonic acid.
$HClO_3$	Chloric acid.

Experiment shows that in each of these oxygen acids, the hydrogen is in more direct relation with certain oxygen atoms than with the rest of the molecule, so that they may be formulated as follows:—

$$(HO)_2SO_2 \quad (HO)NO_2 \quad (HO)_3PO \quad (HO)_2CO \quad (HO)ClO_2$$

It will be seen that all the hydrogen is in the form of hydroxyl.

Hydrogen which is not in this condition in a molecule is not easily replaceable by a positive element, unless united to a strongly negative radicle. Thus in HCl, the hydrogen is easily replaceable by a positive, but not in NH_3. The two conditions of hydrogen may co-exist in a molecule. In hypophosphorous acid, H_3PO_2, experiment shows that only one hydrogen atom is easily replaceable, and the arrangement is considered to be as follows:—

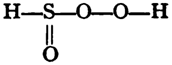


$$\mathrm{H{-}O{-}\underset{\overset{\|}{O}}{\overset{\overset{H}{|}}{P}}{-}H}$$

Only one hydrogen atom is directly united to a strongly negative element.

Such differences in the position and function of hydrogen in the same molecule are unusual in the inorganic acids, which generally have all their hydrogen in either the hydroxyl position or in some similar relation, but nearly all organic acids contain hydrogen which is not replaceable.

In sulfurous acid, H_2SO_3, experiment shows that we probably have the arrangement



$$\mathrm{H{-}\underset{\overset{\|}{O}}{S}{-}O{-}O{-}H}$$

Here both hydrogen atoms are replaceable, because both are directly united to a member of the oxygen group, that is, to strongly negative elements. In thiocarbonic acid, H_2CS_3, in which sulfur takes the place of oxygen, the arrangement is as follows: $(HS)_2CS$; sulfur, selenium and tellurium may in this manner take the place of oxygen in the molecule and render the hydrogen replaceable.

When the molecule contains bodies of high positive character, the power of replacing the hydrogen by other positives does not exist, unless several molecules of oxygen (or S, Se or Te) are also present. It appears then that as the proportion of oxygen is increased in any molecule, without other change, its acid character will be gradually developed. Thus $Cr(HO)_2$ possesses no acid character, but if two atoms of oxygen be added to the chromium, making $(HO)_2CrO_2$, that is, H_2CrO_4, a well marked acid, chromic acid, is produced. It is then, according to the number and position of the negative elements in any molecule that the function of the hydrogen is determined. When strongly positive elements are present, either without negatives or with only relatively few atoms of them, the hydrogen is not easily replaceable by positives, the body is not an acid, but has power to interact with acids and neutralize them. Thus the above mentioned compound, $Cr(HO)_2$, will dissolve easily in sulfuric acid and neutralize it, that is, take away the characteristic properties of the acid, the sour taste, effect on organic colors (see below), and general chemical activity. Substances that act in this manner are called *bases*. The action in the case of chromous hydroxid and sulfuric acid would be thus represented:—

$$Cr(HO)_2 + H_2SO_4 = CrSO_4 + 2H_2O.$$

Further instances are as follows:—

$$\begin{aligned}
NaHO &+ HCl = NaCl + H_2O. \\
NaHO &+ H_2SO_4 = NaHSO_4 + H_2O. \\
2NaHO &+ H_2SO_4 = Na_2SO_4 + 2H_2O. \\
KHO &+ HNO_3 = KNO_3 + H_2O. \\
Cu(HO)_2 &+ H_2SO_4 = CuSO_4 + 2H_2O. \\
Bi(HO)_3 &+ 3HCl = BiCl_3 + 3H_2O. \\
Fe_2(HO)_6 &+ 3H_2SO_4 = Fe(SO_4)_3 + 3H_2O.
\end{aligned}$$

The bodies NaCl, $NaHSO_4$, etc., are called *salts*. A salt may, therefore, be defined as the result of the interaction of an acid with a base.

Since the function of the base in these reactions depends essentially on the strongly positive element, it is not necessary to have it in association with hydroxyl. The formation of salts may take place by the action of acids upon oxids, upon the elements themselves, and also upon compounds containing weaker acid radicles than those existing in the acid employed. Zinc sulfate, for instance, may be made by any of the following methods:—

$$\begin{aligned}
Zn &+ H_2SO_4 = ZnSO_4 + H_2. \\
ZnO &+ H_2SO_4 = ZnSO_4 + H_2O. \\
Zn(HO)_2 &+ H_2SO_4 = ZnSO_4 + 2H_2O. \\
ZnCO_3 &+ H_2SO_4 = ZnSO_4 + H_2O + CO_2.
\end{aligned}$$

Theoretically, therefore, and frequently practically, there may be many methods of producing a salt, but in many cases the affinity of the acid radicle is not sufficient to bring about the change, unless the positive is either in the form of oxid or hydroxid. Thus the reaction—

$$Ag + HCl = AgCl + H$$

will not occur, but either

$$AgHO + HCl = AgCl + H_2O,$$
$$\text{or } Ag_2O + 2HCl = AgCl + 2H_2O$$

will occur.

Intimately connected with this subject is the meaning of the terms *acid*, *alkaline* and *neutral*, as applied to the conditions of substances. If we add a drop of sulfuric acid to a solution of litmus, it becomes red; by the addition of a small amount of magnesia the color will be restored. The magnesia is a base; it has interacted with the acid and deprived it of its chemical activity. By this combination the magnesia has also been neutralized.

Litmus is a color much used for these tests. It becomes red on the addition of an acid, and has the blue color restored on the addition of a base. It is usually sold in the blue condition, and is used either in solution in water or in the form of *litmus paper*—strips of paper soaked in the solution and dried.

A number of artificial colors from coal-tar products are now used as substitutes for litmus. Among these are:—

Phenolphthaleïn—red when alkaline, nearly colorless when acid.

Congo red—red when alkaline, blue when acid.

Lakmoid—similar changes to litmus.

Phenacetolin—pale yellow with acids, pink with alkalies.

These color reactions are of importance in practical chemical operations, but they have little value in determining the theoretical relations between acids, bases and salts, since there are substances which are theoretically acids, yet act on the colors as if alkaline, and the reverse.

The number of atoms of replaceable hydrogen in an acid determines its *basicity*.

HNO_3.	having	one	replaceable	hydrogen	atom,	is	*mono*basic.
H_2SO_4	"	two	"	"	atoms,	"	*di*basic.
H_3PO_4	"	three	"	"	"	"	*tri*basic.
H_4SiO_4	"	four	"	"	"	"	*tetra*basic.

An acid like hypophosphorous, H_3PO_2, is not tribasic, therefore, but monobasic. Similar phrases are applied to bases but more rarely; thus calcium hydroxid, $Ca(HO)_2$, having the power to take up two molecules of any monobasic acid, might be called a di-acid base.

The radicle obtained by deducting all the replaceable hydrogen from an acid is sometimes called the residue of the acid. SO_4, for instance, is the residue of sulfuric acid, NO_3 the residue of nitric acid. The acid radicle proper is the body obtained by deducting all the hydroxyl or hydrosulfyl, etc., from the acid. SO_2 is the radicle proper of sulfuric acid. This distinction in nomenclature is convenient in expressing some of the reactions of these acids.

Salts may be divided into four classes :—

NORMAL SALTS, in which the hydrogen of the acid is replaced by a single element, according to its valencies. The acids themselves are normal salts of hydrogen :—

Na_2CS_3	Sodium thiocarbonate.
KNO_3	Potassium nitrate.

MIXED SALTS, in which two or more positives are present. When some replaceable hydrogen remains, the body is usually called an *acid* salt :—

$HKCO_3$	Acid potassium carbonate.
$KNaC_4H_4O_6$	Sodium potassium tartrate.

DOUBLE SALTS, in which two complete salts of either of the above classes unite to form a definite compound, which is generally distinctly crystalline :—

$K_2SO_4,Al_2(SO_4)_3$	Potassium aluminum sulfate.
$FeSO_4,(NH_4)_2SO_4$	Ammonium ferrous sulfate.
$2KCl,PtCl_4$	Potassium platinum chlorid.

OXY SALTS (sometimes called *basic* salts or *sub* salts), in which oxygen takes the place of one or more of the acid radicles :—

$BiNO_3O$	Bismuth oxynitrate.
$SbOCl$	Antimony oxychlorid.

VOLUME COMBINATION.

If we weigh equal volumes of elements in the state of gas, we find that their relative weights will, with a few exceptions, be in exact proportion to their atomic weights. For instance, a vessel which holds 1 grain of hydrogen (about 47 cubic inches) will hold the following quantities of other elements, it being understood that all the bodies are in the state of gas and at the same temperature and pressure :—

Element.	*Atomic Weight.*	*Wt. of vol. equal to 1 vol. of H.*
O	16	16
S	32	32
Cl	35.4	35.5
I	127	127
Br	80	80

Some of the elements cannot be converted into vapor, and consequently cannot be compared on this system. Among these are carbon, silicon and many of the common metals. These practically resist the action of the highest temperature which can be used in such experiments. A few elements show results which are exceptional; among these are—

Element.	*Atomic Weight.*	*Wt. of vol., equal to 1 vol. of H.*
As	75	150
P	31	62
Hg	200	100

In the case of phosphorus and arsenum the weight is twice as great as analogy would require; in the case of mercury, half as great.

The following law has been established by mathematical and physical investigation: *Equal volumes of elementary gases contain equal numbers of molecules.*

The relative weight of the atoms of each element may be determined by this law. If a given volume of hydrogen contains, say, 1000 molecules, the same volume of oxygen will contain the same number; and as the oxygen volume is 16 times as high as the hydrogen, it is clear that the weight of each molecule of oxygen will be 16 times that of each molecule of hydrogen. The molecules of hydrogen and oxygen each contain two atoms, hence, the atomic weights will also be in the proportion of 16 to 1.

In gases the spaces between the molecules are very large in proportion to the size of the great molecules themselves. Elementary gases combine so as to produce a volume of gas *which is equal to twice the volume that would be occupied by one atomic weight of hydrogen.* The following instances are taken from among the commonest chemical compounds:—

One volume of H and one volume of Cl combine and produce *two* volumes of HCl.

Two volumes of H and one volume of O combine and produce *two* volumes of H_2O.

Three volumes of H and one volume of N combine and produce *two* volumes of NH_3.

If the substances were estimated, say in pints, then the resulting compounds would have the volume of two pints.

Some examples will make this plain:—

47 cubic inches of H, weighing 1 grain, will combine with 47 cubic inches of Cl, weighing 35.4 grains, and produce 94 cubic inches (*i. e.*, 47 × 2) of hydrochloric acid (HCl), weighing 36.4 grains. The ratio of weights of *equal bulks of* hydrochloric acid and hydrogen is not 94 to 1, for the figure

94 is calculated for a molecule of HCl, while 1 represents an atom of H. We must compare molecule to molecule, that is HCl to HH, hence 94 to 2 : : 47 to 1. By dividing 36.4 by 2 we get the weight of a quantity of hydrochloric acid equal to one atomic weight of hydrogen—viz. 18.2. This figure, 18.2 represents, therefore, the density or specific gravity compared to hydrogen.

94 cubic inches of H, weighing two grains, will combine with 47 cubic inches of O, weighing 16 grains, and produce 94 cubic inches of steam, H_2O, weighing 18 grains. If we divide 18 by 2, we get, as before, the density of steam compared to hydrogen—viz. 9.

47 cubic inches of N, weighing 14 grains, will combine with 141 cubic inches (47 × 3) of H, weighing 3 grains, and form 94 cubic inches of amin, NH_3, weighing 17 grains; and this weight, divided by 2, gives 8.5 as the density of amin compared to hydrogen.

These principles are employed in determining the formulæ of bodies. N and O combine to form a body called nitric oxid, which is sometimes written NO and sometimes N_2O_2. The following calculation will show which is correct:—

The formula NO requires—

One volume of N = 14
" " " O = 16
—
30 30 ÷ 2 = 15.

The formula N_2O_2 will require—

Two volumes of N = 28
" " " O = 32
—
60 60 ÷ 2 = 30.

In the first instance the formula would indicate a vapor fifteen times as heavy as hydrogen; in the second case thirty times as heavy. Experiment shows that the gas is actually fifteen times as heavy as hydrogen, and therefore justifies the formula NO.

Since the introduction of a large number of atoms into a molecule does not increase the bulk occupied by a collection of such molecules, it is evident that the intermolecular spaces are much larger than the molecules themselves.

The exact quantitative relations which exist in compounds, and the fact that symbols refer to definite proportions of the elements, enables us to employ the method of simple proportion to calculate the amounts involved in, or resulting from, any chemical combination. If it be required to know how much hydrogen is contained in 40 pounds of water, the formula expressed in quantitative ratio is as follows:—

$$\begin{array}{ll} H_2\ (2 \times 1) & = \ \ 2 \\ O & = 16 \\ \hline H_2O & = 18 \end{array}$$

That is, 18 parts by weight of water contain 2 parts of hydrogen. Hence, 18 : 2 :: 40 : x; the fourth term will be the amount required. Percentage composition is ascertained in this manner. The percentage of oxygen in water is obtained by the following proportion:—

$$18 : 16 :: 100 : x.$$

The fourth term will be found to be 88.89, which is therefore the percentage required. Any chemical formula or reaction may be converted in exact weight expressions. To determine, for instance, how much potassium iodid is required to exactly precipitate one gram of mercuric chlorid, we must first express correctly the reaction, that is, the equation. This is as follows:—

$$HgCl_2 + 2KI = 2KCl + HgI_2$$

The proportions by weights are:—

$$\begin{array}{ll} Hg & = 200 \\ Cl_2 & = \ \ 71 \\ \hline HgCl_2 & = 271 \end{array} \qquad\qquad \begin{array}{ll} K & = \ \ 39 \\ I & = 127 \\ \hline KI & = 166 \end{array}$$

The proportion will be, as the molecular weight of the mercuric chlorid is to that of the potassium iodid, with which it reacts, so is the given weight to that of the iodid required. Care must always be taken to use the molecular weights in the full proportion. In the present calculation, for instance, the molecular weight of the iodid must be doubled, because the chlorid reacts with two molecules. Hence,

$$\overset{HgCl_2}{271} : \overset{2KI}{332}(166 \times 2) :: 1 : x.$$

Calculations of this character are of value to the student, who should practice them. Among other points of interest, they will serve to impress on the mind that formulæ give only ratios by special factors, and do not convey directly the simple proportion. Thus, hydrogen iodid, HI, does not contain equal quantities of H and I; but only equal numbers of atoms. The calculation shows this :—

$$\begin{array}{lcr} H & = & 1 \\ I & = & 127 \\ \hline HI & = & 128 \end{array}$$

Therefore,

$$\begin{array}{llllll} HI & & I & & & \\ 128 & : & 127 & :: & 100 : & 99.2 \text{ per cent. iodine;} \end{array}$$

by which it seems that hydrogen iodid contains less than one per cent. hydrogen.

DESCRIPTIVE CHEMISTRY.

A COMPLETE table of the elements, their valencies, atomic weights and symbols, will be found at the end of the book. The following is a summary of the important groups:—

1. The **Potassium Group** includes hydrogen, lithium, sodium, potassium, rubidium, cesium and silver. They are positive monads, and have high affinity for members of the oxygen and chlorin groups. With oxygen they produce (except hydrogen and silver) powerful corrosive compounds called the alkalies, and on this account are sometimes called the alkali metals. Hydrogen and silver are the only ones that occur free in nature.

2. The **Chlorin Group** includes fluorin, chlorin, bromin and iodin. They are negative monads, and are the only elements which form salts without the aid of some member of the oxygen group. For this reason they have been called the HALOGENS, a word meaning "salt formers."

3. The **Oxygen Group** includes oxygen, sulfur, selenium and tellurium. They are negative dyads, and possess the power of forming, with many elements, bases or acids, according to the proportion in which they are combined.

4. The **Nitrogen Group** includes boron, nitrogen, phosphorus, arsenum, antimony, bismuth and gold. They are of uneven valency, triads or pentads; their electrical relations are irregular, but mostly positive.

5. The **Carbon Group** includes carbon, silicon, titanium, tin and some rare elements. They are tetrads, and generally positive. Boron is sometimes classed here, but it is best placed in the nitrogen group. Platinum may be included here.

6. The **Calcium Group** includes calcium, barium and strontium. They are positive dyads, and form oxids which are slightly soluble in water, but much less caustic or corrosive than the alkalies proper, and are often called alkaline earths. Their sulfates, carbonates and phosphates are practically insoluble in water. Lead is conveniently classed here, but has also strong relations to the carbon group.

7. The **Zinc Group** includes zinc, magnesium, cadmium and beryllium. They are never found free, but are tolerably easily reduced from their com-

pounds. They are positive dyads, and each forms a definite oxid which is insoluble in water, not caustic, but forming well-marked salts.

8. The **Iron Group** is positive, and includes iron, manganese, chromium, nickel, cobalt and probably several other elements the chemistry of which is not well known. They are not found in the metallic state, except in small quantity. Most of them form two sets of compounds, acting in one as dyads, in the other as double tetrads. Several form well marked acid anhydrids. Aluminum has some relations with this group and will be described with it.

9. The **Copper Group** includes copper and mercury, positive dyads, resembling each other in the power of forming two sets of compounds, in one of which they are in the unsaturated condition. In this condition they form chlorids insoluble in water, and are thus partly related to silver.

10. The **Platinum Group.**—A number of elements which are found in association with platinum are usually grouped together under the name of platinum metals. These are palladium, iridium, rhodium, ruthenium and osmium.

Unclassified Elements.—Some of the elements are either so rare that their relations have not yet been satisfactorily studied, or their properties are such as to render it impossible to classify them satisfactorily under any system.

Potassium Group.—The potassium group proper includes potassium, sodium, lithium, rubidium, cesium. They are positive monads, of high affinities. Their compounds are nearly all soluble in water. Their hydroxids are powerfully corrosive, and are known as the caustic alkalies. Hydrogen and silver, being positive monads, are also classed in this group, although they differ from the rest in some points.

HYDROGEN.

Hydrogen, H, 1, exists in water and all organic substances.

It is prepared by the action of electricity on water or dilute acids; also by the action of certain elements on water or acids. With acids the action generally occurs without the aid of heat; with water, sodium and potassium act in the cold; iron, magnesium, zinc, etc., require a high temperature.

$$\begin{aligned} Na + H_2O &= NaHO + H. \\ Mg + H_2O &= MgO + H_2. \\ Zn + H_2SO_4 &= ZnSO_4 + H_2. \end{aligned}$$

The last method is generally used in the laboratory.

Hydrogen is also evolved readily by the action of sodium hydroxid on aluminum.

$$Al_2 + 6NaHO = Na_6Al_2O_6 + H_6.$$

$Na_6Al_2O_6$ is usually called sodium aluminate.

Pure hydrogen is a colorless, tasteless and odorless gas. It is the lightest body known, a litre weighing 0.08961 grm. 100 cubic inches weigh 2.14 grains. It has not been liquified. It will burn in air or oxygen, forming water.

Hydrogen, though not poisonous, will not sustain life; small quantities, when pure, can be inhaled without danger.

Hydrogen is a positive monad, and a standard for valency, atomic and molecular weight and density. It combines with many elements. It is the essential element of acids.

Water, H_2O.—When two volumes of hydrogen and one volume of oxygen are combined, complete condensation takes place and water is formed.

Water exists abundantly, not only collected in masses, as in rivers, lakes and seas, but in combination with many substances and in a state of mixture with inorganic and organic bodies. Air almost always contains some water. Some living structures, as succulent fruits, jelly fish, etc., consist almost entirely of water. In natural conditions water is never pure. The matter ordinarily dissolved varies from five to thirty grains to the gallon. When the quantity greatly exceeds this, and especially when peculiar substances, such as iron or sulfur, are present, it constitutes a mineral water. Sea water is very rich in mineral substances.

The most important varieties of mineral waters are—

Alkaline or carbonated waters, containing various carbonates in solution, generally with a quantity of free carbonic acid.

Chalybeate waters, containing iron, generally as ferrous carbonate, with excess of carbonic acid.

Sulfur waters, containing hydrogen sulfid and other sulfids.

Acid waters, containing some of the stronger acids.

Saline or aperient waters, having large amounts of chlorids and sulfates.

Water combines with many bodies. There are two principal classes of these compounds. In one the water seems to unite as such with the other substance, in the other class the molecule of water is broken up.

Of the first kind of combination instances are seen in common crystals. The blue crystals sold as copper sulfate have the composition $CuSO_4, 5H_2O$. Water that is in this way part of a molecule, and essential to a crystalline form, is called WATER OF CRYSTALLIZATION. Substances that do not contain water of crystallization or which have been deprived of it, are said to be ANHYDROUS. Water of crystallization is usually easily driven out by heat.

The second form of the chemical action of water is seen if we mix water with quicklime; a violent action ensues, and the compound CaH_2O_2 results. A considerable number of oxids are capable of uniting thus with water and forming bodies known as hydroxids.

The oxids which, by addition of water, produce hydroxids are called ANHYDRIDS. By subtracting H_2O from any hydroxid we may reproduce the corresponding anhydrid. Acids in this way furnish anhydrids:—

$$\underset{\text{Sulfuric Acid.}}{H_2SO_4} - H_2O = \underset{\text{Sulfuric Anhydrid.}}{SO_3}.$$

If the acid contains but one atom of hydrogen, we must, of course, double the formula before subtracting. Hence—

$$\underset{\text{Nitric Acid.}}{2HNO_3} - H_2O = \underset{\text{Nitric Anhydrid.}}{N_2O_5}.$$

The term anhydrid generally refers to those bodies which yield acids by addition of water. Those which yield hydroxids capable of neutralizing acids are generally called bases.

Hydrogen Dioxid, hydrogen peroxid, H_2O_2, H—O—O—H.—This body, sometimes called oxygenated water, is prepared by liberating oxygen in the presence of water, or when certain highly oxidized bodies are dissolved, as in the following reaction:—

$$BaO_2 + H_2SO_4 = BaSO_4 + H_2O_2.$$

The presence of a considerable excess of water is necessary to the success of this reaction. Dilute solution of hydrogen dioxid can be conveniently prepared by dissolving sodium dioxid in dilute acid. It is a colorless, transparent, oily liquid, nearly one-half heavier than water; it is without odor, has a bitter taste, blisters the skin and bleaches organic colors. It is decomposed by heat and by many chemical substances, often explosively. The preparation of the concentrated liquid is difficult, but a dilute solution can be easily kept, and is now a commercial article, being used for bleaching hair, and as a disinfecting and oxidizing agent.

POTASSIUM.

Potassium, K, 39, occurs in many rocks and soils and in the ashes of land plants, also as nitrate and chlorid. It is quite soft, quickly tarnishes in the air, and decomposes water rapidly, the escaping hydrogen being so highly heated as to take fire, burning with a purple flame, due to the potassium. Specific gravity, 0.865. It is highly positive, and forms several oxids.

Potassium Hydroxid, KHO, *Caustic Potassa,* is made by boiling potassium carbonate with slaked lime:—

$$CaH_2O_2 + K_2CO_3 = 2KHO + CaCO_3.$$

It is a white, powerfully alkaline solid.

Potassium Carbonate, K_2CO_3, *Salt of Tartar.*—This is extracted from the ashes of land plants. Pure potassium carbonate is white, alkaline and moderately corrosive.

Acid Potassium Carbonate, $KHCO_3$, *Salæratus,* is a white crystalline body, and is used in effervescing mixtures, but acid sodium carbonate has of late years substituted it to a great extent. It is often called *bicarbonate.*

Potassium Sulfate, K_2SO_4, forms hard crystals, not very soluble in cold water.

Acid Potassium Sulfate, $KHSO_4$, is sour and strongly acid to test paper. It is often called bisulfate.

Potassium Nitrate, KNO_3, *Nitre, Saltpetre,* is found on the surface of the soil in India, and may be prepared artificially. Potassium nitrate is used in gunpowder and fireworks.

Gunpowder consists of nitre, charcoal and sulfur. The gases produced at-the moment of explosion are sufficient to occupy about 1200 times the bulk of the powder, and the bursting effect is due to this sudden expansion.

Potassium Chlorate, $KClO_3$.—The salt forms flat, tabular crystals. It melts below a red heat, and at a little higher temperature gives off all its oxygen, leaving potassium chlorid. It is not very soluble in cold water, requiring about sixteen times its weight for solution. It is used largely as a source of oxygen and in medicine.

Potassium Chlorid, KCl, exists in sea-water and in some springs. It resembles common salt.

Potassium Bromid, KBr, forms cubical crystals, soluble in water.

Potassium Iodid, KI, closely resembles the bromid. It is easily soluble in water.

Potassium compounds are mostly soluble in water. A few, however, are so slightly soluble as to afford us serviceable tests.

Platinum chlorid produces with potassium salts, a yellow crystalline precipitate of potassium-platinum chlorid, $2KCl, PtCl_4$.

Tartaric acid gives a white crystalline precipitate of acid potassium tartrate, $KHC_4H_4O_6$.

Potassium compounds give to flame a color which is a mixture of red and violet.

SODIUM.

Sodium, Na, 23.—Common salt, $NaCl$, is the most abundant compound. The ashes of sea plants contain sodium carbonate. Sodium closely resembles potassium, but is a little heavier and not so easily oxidized. The properties of its compounds are also much like those of potassium.

Sodium Dioxid, Sodium Peroxid, Na_2O_2, is now a commercial article and is a very useful oxidizing agent. It is a yellowish solid, very caustic. It dissolves readily in water evolving some oxygen.

Sodium Hydroxid, $NaHO$, *Caustic Soda*, is very strongly alkaline and corrosive. It is prepared from sodium carbonate, in the same manner as potassium hydroxid. It is a powerful poison.

Sodium Carbonate, Na_2CO_3, forms large crystals, having the composition $Na_2CO_3, 10H_2O$, called *sal soda* or *washing soda*. On exposure to air these crystals effloresce, and fall to a white powder.

Acid Sodium Carbonate, $NaHCO_3$, *Baking Soda*, is now much used in effervescing mixtures, such as the common baking powders, which are usually a mixture of cream of tartar and baking soda. Alum and acid calcium phosphate are often used as substitutes for the cream of tartar. The action of the powder is due to the sudden evolution of a large volume of carbon dioxid:—

$$NaHCO_3 + KHC_4H_4O_6 = NaKC_4H_4O_6 + H_2O + CO_2$$

Sodium Sulfate, Glauber's Salt, $Na_2SO_4,10H_2O$, forms large crystals, which are remarkable for being more soluble in water at 93° F. (34° C.) than at any other temperature.

Sodium Nitrate, $NaNO_3$, *Chili Saltpetre*, is used as a fertilizer, and also in the preparation of nitric acid.

Sodium Chlorid, NaCl, *Common Salt*, occurs in thick beds in various parts of the world, and is also prepared from sea water and certain brine springs, by evaporation. It dissolves in about the same amount in hot and cold water.

Sodium Phosphates.—The most important form is disodium acid phosphate, Na_2HPO_4, which is used in medicine. Sodium phosphate, Na_3PO_4, is now made in large quantity as a cleansing agent and for other purposes.

Sodium Tetraborate, $Na_2B_4O_7$. See Boric Acid.

Sodium Silicate. See Silicic Acid.

Sodium Thiosulfate, $Na_2S_2O_3$, is much used in photography under the name *hyposulfite*. Its solution possesses the power of dissolving many of the salts of silver, which are insoluble in water.

Sodium Sulfite, Na_2SO_3, is used as a substitute for sulfurous acid in preventing fermentation, also as a reducing agent.

Sodium compounds give a strong yellow color to flame, and are with very few exceptions quite soluble in water.

Lithium, Li, 7.—Its principal sources are some rather rare minerals. Its salts resemble in the main those of potassium and sodium. Small amounts of lithium compounds are occasionally found in natural waters, constituting the so-called *lithia waters*. Lithium imparts a crimson color to flame.

Cesium, Cs, 133, and Rubidium, Rb, 85.4.—Their compounds are rare and resemble those of potassium. Cesium gives a blue color to flame; rubidium a dark red color.

SILVER.

Silver, Ag, 108.—Silver occurs native—that is, in the free state—in moderate abundance, also as sulfid, chlorid and other compounds. It is nearly always present in small amounts in lead ores. It is white and highly lustrous, easily worked into plates and wire, and a good conductor of heat and electricity. Specific gravity, 10.5. It resists the action of oxygen and of caustic alkalies, but is attacked by sulfur and sulfids and by nitric acid. The sensitiveness of silver salts to light is the basis of photography. Silver ı at 1681° F. (916° C.). For use in the arts it is usually alloyed with co The standard alloy of the English mint (sterling silver) contains $\frac{1}{12}$ cop that of the United States mint (coin silver) $\frac{1}{10}$ copper.

Silver Oxid, Ag_2O.—Oxygen is absorbed by melted silver, but no comb tion is formed. When a solution of a silver salt is treated with potas hydroxid, and the precipitate gently heated, silver oxid is formed.

Silver Nitrate, $AgNO_3$, *Lunar Caustic*, is easily made by dissolving metal in nitric acid.

Silver nitrate forms colorless crystals, very soluble in water, and, mixed with organic matter, blackened by light. It fuses at 426° F, (219° and is often cast in sticks for use as a caustic. The property of formi black, difficultly soluble precipitate with organic matter is utilized in the m facture of hair-dies and marking ink.

Silver Chlorid, AgCl, is found as a mineral, and is easily formed artific by adding any soluble chlorid to silver nitrate :—

$$NaCl + AgNO_3 = AgCl + NaNO_3.$$

It forms a heavy white precipitate like curdled milk, turning violet in light, especially if organic matter be present.

Silver is easily reduced from most of its compounds by heat alone, an reducing agents.

Chlorin Group.—This includes chlorin, bromin, iodin and fluorin, negative monads of high affinity. Chlorin generally expels bromin from combination, and bromin expels iodin.

CHLORIN.

Chlorin, Cl, 35.46.—The most abundant compound is common salt, $NaCl$. Many other chlorids are found as minerals.

Several methods for the preparation of chlorin have been devised; nearly all of them depend upon the oxidation of some chlorid.

(*a*) By heating a mixture of manganese dioxid and hydrochloric acid:—

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$

(*b*) By heating a mixture of common salt, sulfuric acid and manganese dioxid:—

$$MnO_2 + 2NaCl + 2H_2SO_4 = MnSO_4 + Na_2SO_4 + 2H_2O + Cl_2.$$

(*c*) By the action of hydrochloric acid upon potassium chlorate, potassium dichromate or bleaching-powder. These methods yield an impure chlorin, and are suitable for the preparation of small amounts.

The reaction with potassium chlorate may be represented as follows:—

$$2KClO_3 + 4HCl = 2KCl + Cl_2O_4 + Cl_2.$$

Chlorin is a greenish-yellow, highly irritating gas. It can be condensed to a greenish liquid. The gas is about two and a half times as heavy as air; one litre weighs 3.1808 grms.; water dissolves about three volumes, acquiring the color and odor of the gas; the solution, known as *chlorin water*, does not keep well.

The affinities of chlorin are very great. It combines directly with most of the metals, decomposes water, and changes many organic substances. Its affinity for hydrogen is increased by light.

It has many applications as a bleaching and disinfecting agent, but is rarely used in the form of gas, the effects being generally obtained by the use of *bleaching powder* (see hypochlorites).

Chlorin is a monad in its strictly negative relations, *i. e.*, in simple chlorids, but in association with oxygen, it seems to assume higher valencies. It is also capable of replacing hydrogen, atom for atom, giving rise to an important and extensive series of *substitution* compounds, which are considered in connection with organic chemistry.

Hydrochloric Acid, HCl, *Muriatic Acid*, *Spirit of Salt*.—This acid may be formed by the direct union of its elements, but the practical process is the action of common salt and sulfuric acid, according to the following reaction:—

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

This reaction requires a high temperature. In ordinary experiments and on the small scale the reaction is—

$$NaCl + H_2SO_4 = NaHSO_4 + HCl.$$

Hydrochloric acid is a colorless gas of a strong pungent odor and poisonous to animals and plants. Its density is 18.181; a litre weighs 1.63 grms. It does not burn nor support ordinary combustion, but some substances burn in it, forming chlorids. Water will absorb nearly 500 volumes, producing a strongly acid solution, which is the common hydrochloric or muriatic acid. When pure this is a colorless, fuming, strongly acid liquid.

Many metals dissolve in hydrochloric acid, forming chlorids and liberating hydrogen; oxids dissolve, forming chlorids and water; sulfids form hydrogen sulfids, etc. The following reactions illustrate this:—

$$Zn + 2HCl = ZnCl_2 + H_2.$$
$$ZnO + 2HCl = ZnCl_2 + H_2O.$$
$$FeS + 2HCl = FeCl_2 + H_2S.$$

With many oxids, some chlorin escapes, as shown in the reaction with manganese dioxid or lead dioxid. We may assume such reactions to occur in two stages, thus:—

$$PbO_2 + 2HCl = PbCl_2 + H_2O + O.$$

The nascent O oxidizes a further quantity of acid—

$$2HCl + O = H_2O + Cl_2.$$

A mixture of about three parts nitric with five parts hydrochloric acid has been long used under the name *aqua regia* and nitro-muriatic acid. It dissolves gold and platinum, and owes its efficacy in part to the free chlorin which is formed by the oxidizing action of the nitric acid upon the hydrochloric acid.

Compounds of Chlorin and Oxygen.—Several of these are known in the free state. Others are known only in combination, as in the following series:—

$HClO$ . . .	Hypochlorous acid.	$H—O—Cl$.
$HClO_2$ . . .	Chlorous "	$H—O—\overset{III}{Cl}O_2$.
$HClO_3$ . . .	Chloric "	$H—O—\overset{V}{Cl}O_2$.
$HClO_4$ . . .	Perchloric "	$H—O—\overset{VII}{Cl}O_3$.

Any positive may take the place of the hydrogen.

Chloric Acid, $HClO_3$.—When chlorin acts upon metallic oxids or hydroxids at a temperature of over 60° F. (15.5° C.) *chlorates* will be produced, according to the following reaction:—

$$6KHO + Cl_6 = KClO_3 + 5KCl + 3H_2O.$$

The chlorates are useful for the large amount of oxygen which they contain, and which they yield easily when heated. Potassium chlorate is the substance from which oxygen is usually prepared. Perchloric acid is obtained by heating dilute chloric acid. The perchlorates resemble the chlorates.

When chlorin acts upon hydroxids, especially calcium hydroxid, at a low temperature, hypochlorites are produced. (See calcium hypochlorite.) A weak solution of hypochlorous acid is sometimes used for removing ink.

Chlorin combines with nitrogen to form a body called nitrogen chlorid. It is an oily liquid, which decomposes very easily and with violent explosion.

BROMIN.

Bromin, Br, 80.—Bromids occur in sea water, sea plants, brine springs and in a few minerals. Bromin may be prepared by processes analogous to those of chlorin—acting upon bromids by means of oxidizing agents, such as a mixture of sulfuric acid and manganese dioxid:—

$$2KBr + MnO_2 + 2H_2SO_4 = K_2SO_4 + MnSO_4 + 2H_2O + Br_2.$$

It may also be directly expelled by the superior affinity of chlorin:—

$$KBr + Cl = KCl + Br.$$

Bromin is a dark red liquid, which at ordinary temperatures evolves irritating red vapors. This liquid is three times as heavy as water, and boils at 145° F. (63° C.) and freezes at —12° F. (—25° C.). It is soluble in water, and is often conveniently used in that form. Its chemical properties are similar to those of chlorin, but not so energetic. It bleaches vegetable colors and decomposes many organic bodies.

It combines energetically, forming bromids, of which those of hydrogen, potassium and ammonium are the most important. It also forms oxygen compounds analogous to those of chlorin.

Hydrogen Bromid, Hydrobromic Acid, HBr.—This substance cannot be conveniently prepared by the action of sulfuric acid upon a bromid, but is obtained by using a mixture of phosphorus, powdered glass and bromin, or by the action of phosphoric acid upon a bromid. It resembles hydrochloric acid in its properties, and is used in medicine.

Salts of *Bromic Acid*, $HBrO_3$, and *Hypobromous Acid*, HBrO, are also known. They closely resemble the corresponding chlorin compounds.

IODIN.

Iodin, I, 127.—Iodids occur in association with bromids and chlorids in sea water and sea plants.

Iodin is prepared from any iodid, by processes similar to those for bromin, either by the action of chlorin or of a mixture of manganese dioxid and sulfuric acid. The reactions are—

$$KI + Cl = KCl + I,$$

or,

$$2KI + MnO_2 + 2H_2SO_4 = K_2SO_4 + MnSO_4 + 2H_2O + I_2.$$

It forms bluish-black crystalline masses with metallic lustre. It evaporates slowly at ordinary temperatures, melts at 225° F. (107° C.), and boils at 347° F. (175° C.). The vapor has a deep violet color and a peculiar odor, somewhat like that of chlorin, but is not so irritating. The solid dissolves in alcohol, ether and carbon disulfid; also in water containing potassium iodid; only slightly in pure water. It has some bleaching, oxidizing and disinfecting powers. One of its important properties is that of producing a blue color with starch. For this action the iodin must be in the free state; the iodids give no color.

The chemical relations of iodin are substantially the same as those of chlorin and bromin.

Hydrogen Iodid, HI, *Hydriodic Acid*.—This is prepared by methods similar to those used for hydrogen bromid, which body it closely resembles. It is used in medicine.

By the action of strong ammonium hydroxid upon powdered iodin a brownish substance is produced, having probably the composition NHI_2. It is easily handled while wet, but when perfectly dry it explodes, with a loud report, on the slightest touch.

FLUORIN.

Fluorin, F, 19.—This is tolerably abundant in fluor spar, CaF_2, and cryolite, $3NaF,AlF_3$, and some rarer minerals. It exists in the stems of grasses and in bones and teeth.

Fluorin is a gas, the properties of which have only lately been studied, on account of the difficulty of obtaining it. It combines with every known element except oxygen. It is remarkable for its affinity for silicon.

Hydrogen Fluorid, Hydrofluoric Acid, HF.—This body is prepared by acting on calcium fluorid, CaF_2, with sulfuric acid. The pure HF is a gas, but will dissolve in water. It acts powerfully, especially on siliceous materials. It is used for etching designs on glass.

Strong solution of hydrogen fluorid is now sold in gutta-percha bottles or paraffin, upon which it has no action.

Oxygen Group.—This includes oxygen, sulfur, selenium and tellurium, negative dyads.

OXYGEN.

Oxygen, O, 16.—This exists in water, air, all animal and vegetable tissues and in the great majority of minerals. It constitutes over half the matter composing the earth.

Several oxids are decomposed by heating. The decomposition of mercuric oxid in this manner was the means of the discovery of the gas, the reaction being: $HgO = Hg + O$.

Chlorates and nitrates are decomposed by heat, giving off large quantities of oxygen, but not always quite pure. Potassium chlorate mixed with about one-quarter of its weight of manganese dioxid is preferred.

The reaction concerns the potassium chlorate only, which is simply decomposed—

$$KClO_3 = KCl + O_3.$$

The exact manner in which manganese dioxid acts has not been explained.

Oxygen is colorless, odorless, and tasteless; it is one-tenth heavier than air, one litre weighing 1.43 grm. It is continually being absorbed by living animals in the process of respiration, to which function it is essential, and is also consumed in ordinary combustion. All bodies which burn in air burn with increased brilliancy and rapidity in pure oxygen.

Plants under the influence of light both excrete and absorb oxygen.

Oxygen combines with every other element except fluorin, and with many in several proportions. The chemical functions of these oxids are dependent in part upon the number of oxygen atoms present. Those of manganese may be taken as examples:—

MnO	Powerful base.
Mn_2O_3	Weak base.
MnO_2	Indifferent.
MnO_3	Forming an acid (anhydrid).

These illustrate the law that small proportions of oxygen tend to produce bases, high proportions anhydrids- or acid-forming oxids, and intermediate proportions bodies of uncertain or indifferent character. Elements of intermediate electrical character are incapable of forming basic oxids. Thus, nitrogen forms five oxids, but none of them has basic powers, but several form powerful acids.

Oxygen is slightly soluble in water, and upon this fact depends the existence of most forms of aquatic life.

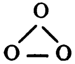
The removal of oxygen from any compound is called *reduction ;* the addition of oxygen is called *oxidation.* Substances which bring about the former action are called *reducing* agents, those causing the latter effect, *oxidizing* agents. The terms are now extended to actions involving the removal or addition of other negative elements. Thus the conversion of ferric chlorid into ferrous is called a reduction, and the reverse operation (ferrous chlorid into ferric) is called an oxidation.

Ozone.—Ozone is a modified form of oxygen in which three atoms constitute a molecule. The contrast between the conditions is shown thus:—

Ordinary Oxygen.

$$O=O$$

Ozone.



Ozone may be prepared by passing electrical sparks through air or oxygen, by the slow oxidation of phosphorus or of turpentine, or other essential oils, by the decomposition of water by the galvanic current, by the action of acids upon certain bodies rich in oxygen. By all these methods only a small proportion of the oxygen is converted into ozone. When barium dioxid or potassium permanganate is mixed with strong sulfuric acid, some ozone forms:—

$$3BaO_2 + 3H_2SO_4 = 3BaSO_4 + O_3.$$

Ozone is heavier than oxygen, and soluble in water.

When the properties of an element are modified without alteration of composition, the change is said to be *allotropic.* Ozone is an allotropic form of oxygen.

SULFUR.

Sulfur, S, 32, occurs native—*i. e.*, in the free state; also in combination, forming sulfids and sulfates, and in some animal and vegetable structures.

It is seen in several forms; *roll sulfur or brimstone*, made by casting the melted sulfur in moulds; *flowers of sulfur*, made by condensing the distilled sulfur in a cool chamber, and *precipitated sulfur*, a finely-divided medicinal form, prepared by precipitation.

Ordinarily, sulfur is a brittle, yellow solid, insoluble in water, highly combustible, fusible at about 250° F. (121° C.) and boiling at 836° F. (447° C.). It is a non-conductor of electricity, and becomes highly electrical by friction.

It assumes several allotropic forms, among which is a somewhat plastic mass, made by rapidly cooling melted sulfur. This form is not permanent, but soon changes to the ordinary form.

Like oxygen, it combines directly, when heated, with many metals. In these compounds the sulfur is negative, and usually dyad. With the members of its own group it combines in several proportions, showing valencies of two, four, and six, and perhaps even higher. In combination with oxygen and chlorin it is regarded as positive to them. In general its compounds are analogous in composition to those of oxygen, and since many oxids act as bases toward the ordinary acids, so the corresponding sulfids act as bases toward what are called the sulfur acids. In such compounds the sulfur is substituted for the oxygen, atom for atom, and the name is formed by prefixing either the syllable "*sulph*" or "*thio*" to the name of the acid. The latter prefix is now preferred. Thus we have—

$K_2O + CO_2 = K_2CO_3$ . . . . . . Potassium carbonate.
$K_2S + CS_2 = K_2CS_3$ . . . . . . Potassium thiocarbonate.

Sulfur is used in the arts for vulcanizing caoutchouc and in the manufacture of gunpowder. Match-sticks are tipped with it to make the friction composition ignite the wood more surely.

Sulfur forms two compounds with hydrogen:—

H_2S . . . . . . Hydrogen sulfid.
H_2S_2 . . . . . . Hydrogen disulfid.

Hydrogen Sulfid, H_2S.—This substance is a gas. It exists in solution in some spring waters, also in the emanations from decomposing animal and vegetable matters. It may be made by acting upon sulfids with strong acids. Ferrous sulfid and sulfuric acid are used:—

$$FeS + H_2SO_4 = FeSO_4 + H_2S.$$

Hydrogen sulfid may also be obtained by heating a mixture of hydrochloric acid and antimony sulfid. $Sb_2S_3 + 6HCl = 2SbCl_3 + 3H_2S$.

Hydrogen sulfid is a colorless gas, of disagreeable odor, and is easily combustible. Water at ordinary temperature dissolves about three volumes, acquiring the odor and chemical properties of the gas. The important property of hydrogen sulfid is its power of precipitating many elements as sulfids. These precipitates being generally distinct in color and highly insoluble, their production is not only a test for the presence of such bodies, but also a means of separating them from solution.

Hydrogen Disulfid, HS, H–S–S–H.—This substance is a yellow oily liquid, of a disagreeable odor, decomposing easily, and is analogous to hydrogen dioxid.

Compounds of Sulfur with Oxygen.—Sulfur forms with oxygen a number of acid-forming oxids or anhydrids, some of which are known only in the hydroxid condition—that is, as acids. The important ones are:—

Anhydrid.	*Acid.*	*Name.*
SO	H_2SO_2	Hyposulfurous.
SO_2	H_2SO_3	Sulfurous.
SO_3	H_2SO_4	Sulfuric.
	$H_2S_2O_3$	Thiosulfuric.

The commercial hyposulfites are salts of thiosulfuric acid, properly called thiosulfates.

Sulfur Dioxid, Sulfurous Anhydrid, SO_2.—This substance is the usual product of the burning of sulfur or the sulfids in air or in oxygen. It may also be obtained by deoxidizing sulfuric acid with copper, mercury, charcoal, silver, or sulfur.

The reaction in the preparation of it by the action of sulfuric acid on copper is—

$$Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2.$$

Mercury and silver also give similar effects. Carbon and sulfur act as follows:—

$$C + 2H_2SO_4 = 2SO_2 + 2H_2O + CO_2.$$
$$S + 2H_2SO_4 = 3SO_2 + 2H_2O.$$

Sulfur dioxid can also be obtained by the action of ordinary acids, *e. g.*, sulfuric, on sulfites.

Sulfur dioxid is a colorless gas, of the well-known odor of burning matches. It can easily be condensed to a colorless liquid by a mixture of snow and salt. The liquid is sulfur dioxid, SO_2, and not sulfurous acid. Sulfur dioxid in water forms sulfurous acid, $H_2O + SO_2 = H_2SO_3$ (HSO_2HO) which remains in solution, giving the liquid all the common properties of an acid. The solution is also a powerful reducing agent, and has moderate bleaching power. It slowly becomes converted into sulfuric acid when exposed to air.

The anhydrid, free acid, and its salts are antiseptic agents—that is, prevent putrefaction and fermentation. They act by killing the minute organisms which are the causes of such changes.

The salts of sulfurous acid are called sulfites; monads form two compounds, acid and normal. Thus, potassium gives us—

Acid Potassium Sulfite.	Potassium Sulfite.
$KHSO_3$.	K_2SO_3.

Dyads give one sulfite. From calcium we have but $CaSO_3$.

Sulfur Trioxid, Sulfuric Anhydrid, SO_3, is a soft, white, odorless solid, in long, silky crystals like asbestos. Exposed to the air, it absorbs water rapidly and becomes converted into sulfuric acid.

Sulfuric Acid, $H_2SO_4(HO)_2SO_2$, *oil of vitriol,* occurs in waters of volcanic and mining districts, and in the air of towns, in the latter case derived from the oxidation of sulfurous acid. The compounds of sulfuric acid (sulfates) are of frequent occurrence. Calcium and barium sulfates are abundant minerals; sodium sulfate occurs in many natural waters.

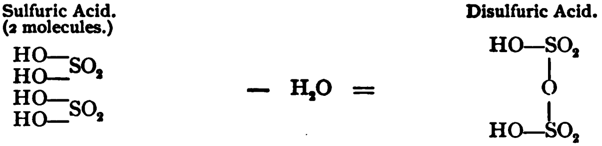
The original method of preparation was the distillation of the sulfates, especially the ferrous sulfate, $FeSO_4$. The acid so formed is more concentrated than the ordinary commercial article. This latter is made as follows: Vapors of nitric and sulfurous acids are mixed with steam and air in a large leaden room, the floor of which is slightly inclined and covered by a few inches of water. The sulfurous acid is derived either from the burning of raw sulfur or the roasting of pyrites; the nitric acid, from the action of sodium nitrate on sulfuric acid. The chemical changes are somewhat complicated, and are not wholly understood.

Pure sulfuric acid is a colorless, oily liquid, of a specific gravity of 1.848, boiling at about 640° F. (338° C.). It is highly corrosive and poisonous. Exposed to the air, it absorbs water in considerable amount. When added to water it produces heat, and the dilution of any considerable quantity must be performed by slowly pouring the acid into the water with constant stirring. Sulfuric acid will decompose many organic substances, extracting the hydrogen and oxygen in the proportion to form water, and leaving the carbon. Commercial sulfuric acid is usually more or less brown, or even black, from the carbon set free from particles of dust, straw, etc., which accidentally fall into it. It always contains a small quantity of water—about one molecule to twelve of acid:—

$$H_2O + 12H_2SO_4.$$

Its properties, boiling point, etc., are practically the same as those of the pure acid.

Nordhausen or Fuming Sulfuric Acid, the original *oil of vitriol,* is obtained by the distillation of green vitriol. It corresponds to the formula $H_2S_2O_7$, being two molecules of sulfuric acid minus one of water, $2H_2SO_4 - H_2O = H_2S_2O_7$. Acids derived in this way are known as di-acids or pyro-acids. The graphic formulæ are as follows :—



Sulfuric Acid. (2 molecules.)

Disulfuric Acid.

$$\begin{array}{l} \left.\begin{array}{l} HO— \\ HO— \end{array}\right. SO_2 \\ \left.\begin{array}{l} HO— \\ HO— \end{array}\right. SO_2 \end{array} \quad - \ H_2O \ = \quad \begin{array}{c} HO—SO_2 \\ | \\ O \\ | \\ HO—SO_2 \end{array}$$

It is denser and even more corrosive than the common acid, and unites with water with great energy. It is used for dissolving indigo and for a few other purposes. When heated, sulfur trioxid distils off, and the ordinary acid is left.

The properties of sulfuric acid are greatly modified by dilution ; its corrosive and charring action may be entirely removed by adding much water.

The salts of sulfuric acid are called sulfates. Monads give, of course, two sulfates, acid and normal. Sodium gives us—

Acid Sodium Sulfate.	Sodium Sulfate.
$NaHSO_4$.	Na_2SO_4.

Dyads give one sulfate. From barium we get only $BaSO_4$ barium sulfate.

Most sulfates, except those of the calcium group, are freely soluble in water.

The commercial sulfuric acid contains several impurities, of which the most important are arsenic and lead.

Thiosulfuric acid, $H_2S_2O_3$, commonly but erroneously called hyposulfurous acid, has not been obtained in the free state. Sodium thiosulfate is much used in photography. These compounds may be regarded as sulfuric acid in which one atom of oxygen is replaced by sulfur ; hence thiosulfuric, not thiosulfurous, acid. Its graphic formula may be given thus : $HS—SO_2—OH$. The thiosulfates are powerful reducing agents.

Sulfur forms several compounds with chlorin : S_2Cl_2, sulfur chlorid ; SCl_2, sulfur dichlorid ; SCl_4, sulfur tetrachlorid.

Selenium, Se, 79.5, is found native and also as selenids. It is rare.

The physical properties of selenium resemble those of sulfur. It shows several allotropic forms.

The compounds of selenium are analogous to those of sulfur ; we have—

H_2Se	Hydrogen selenid.
SeO_2	Selenium dioxid.
H_2SeO_3	Selenous acid.
H_2SeO_4	Selenic acid.

Tellurium, Te, 128, is found native, and also in union with bismuth, gold, etc. It is rare.

It has a metallic lustre and pinkish color, fuses just below a red heat, and boils at a somewhat higher temperature.

Calcium Group.—This includes calcium, barium, and strontium. They are positive dyads, and form oxids slightly soluble in water; those of the first three were formerly called the alkaline earths. The sulfates are insoluble or sparingly soluble in water. Lead is conveniently described with this group.

CALCIUM.

Calcium Ca, 40, occurs mainly in the form of sulfate, carbonate, phosphate, and fluorid. It is light yellow and malleable; it oxidizes easily.

Calcium Oxid, Quicklime, CaO, obtained by heating the carbonate to redness ($CaCO_3 = CaO + CO_2$), is a white, infusible solid, which neutralizes the most powerful acids and combines with water with great energy, forming

Calcium Hydroxid, Slaked Lime, CaH_2O_2, a soft, white, caustic powder, slightly soluble in cold water (about 9 grains to the pint). The solution is known as *lime-water;* a thick mixture of calcium hydroxid with water is known as milk of lime.

Calcium Carbonate, $CaCO_3$. In a non-crystalline condition this is seen as *chalk, marble,* and *limestone;* in crystals it forms *Iceland spar* and *arragonite.* It is the chief constituent of shells. It may be prepared by adding sodium carbonate to calcium chlorid:—

$$CaCl_2 + Na_2CO_3 = CaCO_3 + 2NaCl,$$

or by passing carbon dioxid through calcium hydroxid solution.

It is a white solid, almost insoluble in pure water. It dissolves more freely in water containing carbon dioxid, hence many natural waters contain it. When present in an amount more than a few grains to the gallon, a *hard* water is formed, which has the property of curdling soap and preventing the formation of a lather, due to precipitation of insoluble calcium salts, formed from the soap. Boiling expels carbon dioxid, precipitates the calcium carbonate, and softens the water. The excess of carbon dioxid will also be lost by exposure to air, and calcium carbonate will then be deposited. Such an action occurs in caves, forming *stalactites* and *stalagmites*.

Calcium Sulfate, $CaSO_4$, usually occurs crystallized with $2H_2O$, constituting *selenite*, *gypsum*, and *alabaster*, sometimes, however, anhydrous. It is soluble in about 400 times its weight of cold water. It is a frequent ingredient of natural water, causing the same effect of hardness mentioned above; but as it does not owe its solubility to carbon dioxid, boiling does not soften the water, and hence the condition is called *permanent* hardness. When the crystallized mineral is heated moderately, it loses water and becomes a soft white powder, *plaster-of-Paris*, which when mixed again with water reabsorbs it and becomes a hard mass, expanding slightly in bulk, and thus suited for taking casts of any object.

Calcium Phosphate, $Ca_3(PO_4)_2$, occurs in bone and in modified form in some mineral deposits. Its chief use is in fertilizers and in the manufacture of phosphorus and its compounds. It is insoluble in water, but soluble in dilute acids.

Calcium Hypophosphite, $Ca\ (PH_2O_2)_2$, is used in medicine.

Calcium Chlorid, $CaCl_2$, is obtained by acting on the carbonate with hydrochloric acid:—

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2.$$

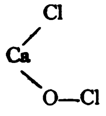
It is very soluble in water. It has a powerful affinity for water, and is used for drying gases.

Calcium Hypochlorite, *Bleaching Powder*, *Chlorated Lime*.—This is produced by passing chlorine into slaked lime, keeping the mixture cool.

The exact composition of the commercial bleaching powder is undetermined; it contains some unchanged calcium hydroxid, and exhibits the reactions of a mixture having the formula—

$$Ca(ClO)_2 + CaCl_2,$$

but is considered by some to be more accurately expressed by the formula—



Bleaching powder, when in good condition, is a loose, dry, white powder, with a faint and not disagreeable odor. If it smells of chlorin it is in bad condition. It dissolves in water. The solution possesses strong bleaching and disinfecting powers, for which purposes it is largely used. Acids, even carbonic acid, decompose it, setting chlorin free. The commercial salt is often erroneously called *chlorid of lime*.

Calcium Fluorid, CaF_2, is found as the mineral, *Fluor Spar*. Small quantities exist in bones and teeth.

Calcium compounds give to flame a reddish color.

BARIUM.

Barium, Ba, 137, occurs as sulfate and carbonate. It is a moderately heavy, pale yellow, easily oxidized solid.

Barium Oxid, Baryta, BaO, easily takes up water, forming barium hydroxid, BaH_2O_2, which is soluble in water.

Barium Dioxid, BaO_2, is used in making hydrogen dioxid.

Barium Carbonate, $BaCO_3$, is found in nature as *witherite*. It is nearly insoluble in water.

Barium Sulfate, $BaSO_4$, *Barytes*, is found abundantly as the *gangue* or rock surrounding metallic veins. It is heavy, white, and nearly insoluble in water. It is used as a substitute and adulterant for white lead, and also as a source of the other barium salts.

Barium Nitrate, $Ba(NO_3)_2$, is used in making green fire.

Barium Chlorid, $BaCl_2$, is used as a test solution for sulfates.

Barium communicates to flame a yellowish-green color. Sulfuric acid produces in barium solutions a white precipitate of barium sulfate, insoluble in acids or alkalies.

STRONTIUM, Sr, 87.5, resembles barium in its compounds and chemical relations. It occurs as sulfate and carbonate.

Strontium Nitrate is used in making red fire.

Strontium compounds give to flame a crimson tint. Its solutions produce with sulfuric acid a white precipitate resembling that given by barium.

LEAD.

Lead, Pb, 207, occurs as sulfid (*galena*), carbonate, sulfate, and phosphate. Its chemical functions ally it with several groups. It is generally a dyad, and since it forms a dioxid and its sulfate is nearly insoluble in water, it is best considered at this point. It shows tetrad valency that connects it with the carbon group, and has also some resemblances to silver.

Lead is a soft solid, but resists the action of air and of some strong acids, for which reason it is used in chemical apparatus. Pure water, free from air, has little action on lead, but aërated water oxidizes and dissolves it in small quantity. Phosphates, carbonates, and silicates interfere with this action, because they precipitate insoluble lead compounds. Lead melts at 617° F. (325° C.). Specific gravity, 11.5.

Some important alloys are: *type-metal*, containing 4 parts lead and 1 part antimony; *solder*, about equal parts of lead and tin; *pewter*, 1 part lead and 4 parts tin.

Lead Monoxid, PbO, *Litharge*, *Massicot*, is a yellowish or reddish powder, slightly soluble in water and neutralizing the most powerful acids. It fuses at a red heat, and in this condition combines easily with silica, for which reason it is often used in glazing earthenware, but such glaze is easily attacked by acids and may give rise to lead poisoning.

Lead Dioxid, PbO_2, *Puce*, is a brown powder, insoluble in water. It may be regarded as the anhydrid of plumbic acid, H_4PbO_4.

Red Lead, *Minium*, usually Pb_3O_4.—It forms a bright powder, not constant in composition. It may be regarded as lead plumbate, Pb_2PbO_4.

Lead Sulfid, PbS, is abundant as a mineral, *galena*, forming large, cubical, lead-colored crystals. It can be formed by adding hydrogen sulfid to lead solutions.

Lead Carbonate, $PbCO_3$, occurs as a mineral, but is made artificially on a very large scale for use in paints. The *white lead* of commerce is an hydroxy-salt of varying composition, approximately $2PbCO_3 + PbH_2O_2$.

Lead Sulfate, $PbSO_4$, is a white insoluble powder, produced by adding sulfates to lead solutions.

Lead Chlorid, $PbCl_2$, forms slender crystals, not very soluble in cold water.

Lead Iodid, PbI_2, yellow crystalline powder, sparingly soluble in cold water.

Lead Chromate, $PbCrO_4$, *Chrome Yellow*, is described under chromium.

Copper Group.—This includes copper and mercury. They are positive dyads, but also form a series of unsaturated compounds.

COPPER.

Copper, Cu, 63.5, occurs native in large masses, also as sulfid (copper pyrites), and as oxid, silicate and carbonate. In small amounts it is widely distributed in nature, occurring in many articles of food, and generally in the human body, especially in the liver and brain. Copper is distinguished by its red color. It is heavy, specific gravity, 8.9; hard, and can be worked into thin plates or wire; melts at 1996° F. (1901° C.). It conducts heat and electricity very well, and resists the action of the air, but is slightly oxidized and dissolved by acids when in contact with air. Salt water and the acids of fruits will produce this effect, and hence the danger of using copper vessels for kitchen purposes. Copper furnishes some valuable alloys —brass, gun-metal, etc. It forms two sets of salts; in the *cupric* series, the metal is dyad and saturated; in the other, *cuprous*, the copper is unsaturated. The cuprous salts are mostly colorless and tend to absorb oxygen or other negatives, becoming saturated (cupric) compounds; the cupric salts are green or blue.

Copper Monoxid, CuO, *Cupric Oxid, Black Oxid*, is a heavy, black powder. Copper hydroxid, CuH_2O_2, formed when copper salts are mixed with sodium hydroxid, is a bluish green mass, dissolving in ammonium hydroxid, producing a clear, deep-blue liquid; but with sodium hydroxid no solution occurs except in the presence of certain organic bodies, especially sugar, when a clear blue solution is also formed. If a solution containing sugar is boiled, the cupric hydroxid is changed to cuprous oxid, which is precipitated as a red or orange powder.

Copper Carbonate, $CuCO_3$, appears not to be known in the pure state. Various oxycarbonates, malachite, and azurite exist as minerals, and similar compounds are obtained by the addition of carbonates to copper salts.

Copper Sulfate, $CuSO_4$, *Blue Vitriol, Blue Stone*, forms large blue crystals soluble in water, and having the composition $CuSO_4$, $5H_2O$.

Copper Chlorid, $CuCl_2$, is in green crystals, soluble in water.

Copper Arsenite, $CuHAsO_3$, *Scheele's or Paris Green*, is a bright green powder. It is used for killing potato-bugs and also as a color. It is a violent poison. A compound containing copper acetate and arsenite is known as Schweinfurth green.

Cuprous Salts.—*Cuprous Oxid*, Cu_2O, is the result of the reducing action of sugar on a mixture of sodium hydroxid and cupric hydroxid. *Cuprous Chlorid*, CuCl, is a white solid, insoluble in water. The cuprous salts are easily converted into cupric.

Copper gives a green tint to flame. Potassium ferrocyanid gives a mahogany brown precipitate of copper ferrocyanid. A clean piece of iron immersed in a solution of copper becomes quickly covered with a bright red coating of copper. This is an easy method for detecting it in pickles, green peas, etc., which are often colored by copper.

MERCURY.

Mercury, Hg, 200.—This metal is found native, and as sulfid (cinnabar). It is liquid at the ordinary temperature, freezing at —40° F. and C., and boiling at 675° F. (357° C.); when pure it does not tarnish in dry or moist air, but above 300° C. it absorbs oxygen. It is very lustrous and heavy; specific gravity, 13.56. Combinations of mercury with other metals are known as *amalgams*. These are either soft or hard, according to the quantity of mercury used. Two series of salts are known, corresponding to the copper salts, and called respectively *mercurous* and *mercuric* salts.

Mercuric Oxid, HgO, *Red Precipitate*, is a red or yellowish-red powder. It is an active base.

Mercuric Sulfate, $HgSO_4$, is a white powder, which is decomposed by water, forming a yellow oxysulfate, $HgSO_4 + 2HgO$, called *turpeth mineral*.

Mercuric Nitrate, $Hg(NO_3)_2$, is generally seen in solution with excess of nitric acid, forming the *acid mercury nitrate* used in medicine.

Mercuric Chlorid, $HgCl_2$, *Corrosive Sublimate*, is a heavy, white, crystalline powder, soluble in water and ether, and having an acrid, metallic taste. It is extremely poisonous, about three grains being a fatal dose. It forms with albumin an insoluble precipitate. Dilute solutions of mercuric chlorid are now much used as an antiseptic in surgery.

Mercuric Iodid, HgI_2, *Red Iodid*, is formed when mercuric chlorid is mixed with potassium iodid:—

$$HgCl_2 + 2KI = HgI_2 + 2KCl.$$

It is at first yellow, but changes to a brilliant scarlet.

Mercuric Sulfid, HgS, *Vermilion*, *Cinnabar*, is an important ore of mercury.

The *Mercurous Salts* are mostly of little importance.

Mercurous Oxid, Hg_2O, is a black powder, easily decomposed.

Mercurous Chlorid, HgCl, *Calomel*, is a white, heavy, tasteless powder, insoluble in water.

Mercuric salts give with potassium iodid a yellow precipitate of HgI_2, changing to scarlet and soluble in excess of the precipitant.

Any compound containing mercury will give with Reinsch's test (*q. v.*) a bright silvery coating on copper foil, easily driven off by heat.

Zinc Group.—This includes zinc, magnesium, and cadmium. They each form but one definite oxid, which is insoluble in water, not caustic, capable of forming well-marked salts. Beryllium, a rare element, is also included in this group.

ZINC.

Zinc, Zn, 65.5, exists as sulfid (*blende*), carbonate (*calamine*), silicate (*electric calamine*), and as oxid. It is hard, bluish-white, generally decidedly crystalline. Sp. gr. 7.14. It melts at 770° F. (410° C.), and distils at about a red heat. It is brittle at ordinary temperatures. When highly heated it burns with a greenish-white flame, producing ZnO. Acids and strong alkalies dissolve it. It is employed in making several important alloys, as brass and gun-metal, which contain copper and zinc, and German silver, which contains copper, zinc, and nickel. Galvanized iron is simply iron covered with a layer of zinc by dipping it in a bath of melted zinc. Commercial zinc is very likely to contain arsenic.

Zinc Oxid, ZnO, *Zinc White*, is a soft powder, yellow when hot, white when cold. It is used as a paint, as an application in surgical dressings, and as a face powder.

Zinc Hydroxid, ZnH_2O_2, is a white body, soluble in acids and alkalies.

Zinc Sulfate, $ZnSO_4$, *White Vitriol*, forms white crystals having the formula $ZnSO_4, 7H_2O$. They are soluble in water, and act as an emetic.

Zinc Chlorid, $ZnCl_2$, forms white masses, which absorb water rapidly from the air (*deliquesce*) and make a strong solution. Zinc chlorid is a powerful corrosive, coagulates albuminous matter, and is used as a preservative in anatomical preparations, also as an application in dentistry. When a strong solution of zinc chlorid is mixed with zinc oxid, the two combine and form a hard, white, insoluble mass which is used as a filling for teeth.

Zinc Phosphate, made by mixing zinc oxid with phosphoric acid, has come into use lately as a substitute for the oxychlorid in filling teeth.

A white precipitate of zinc sulfid is thrown down by the action of hydrogen sulfid on alkaline solution of zinc salts.

MAGNESIUM.

Magnesium, Mg, 24.3, occurs as a carbonate (*magnesite*), silicate (*talc* and *soapstone*), also as hydroxid and chlorid. Most natural waters contain magnesium compounds. It is a bright, malleable solid. Sp. gr. 1.74. When strongly heated in the air it burns with a bright light, producing MgO. Magnesium compounds cause *hardness* in water similar to that produced by calcium salts.

Magnesium Oxid, MgO, *Magnesia,* is a light, white powder, insoluble in water, and neutralizing acids.

Magnesium Carbonate, $MgCO_3$, occurs as a mineral (*magnesite*). The artificial form, known as *magnesia alba,* is an oxycarbonate.

Magnesium Sulfate, $MgSO_4$ *Epsom Salt,* forms colorless crystals, having the composition $MgSO_4$, $7H_2O$. It is very soluble in water.

Magnesium Chlorid, $MgCl_2$, resembles zinc chlorid in some respects, but does not have the same corrosive action. When mixed with magnesium oxid it sets to a hard mass.

CADMIUM, Cd, 112, occurs in zinc ores. It is silver-white and crystalline. Sp. gr. 8.6. It melts at 442° F. (228° C.), and is nearly as volatile as mercury. It is easily dissolved by ordinary acids. CdS is obtained as an orange-yellow precipitate by passing hydrogen sulfid into solutions of cadmium compounds.

Iron Group. Strictly this includes only iron, manganese, and chromium. They form two series of salts, in which they are respectively dyads and either triads or tetrads; the tetrad form is supposed to act as a double atom, as explained under iron. Aluminum is included here because it forms compounds agreeing with the higher series of iron salts. Nickel and cobalt are included, because of several resemblances to iron.

Chemists do not agree as to the proper method of formulating the higher (ic) series of compounds of this group. It is pointed out in the chapter on Valency, that it may be assumed that in such compounds the actual valency is four, but that by saturation between like atoms, the effective capacity of each is reduced to three, and graphic formulæ are given to show the application of this theory. Under this view ferric chlorid will be written Fe_2Cl_6, aluminum chlorid, Al_2Cl_6. At the present day, however, the tendency is to divide these formulæ, writing $FeCl_3$, $AlCl_3$, considering the positive elements as triads. This is contrary to formerly accepted opinion that valencies increase or diminish by two degrees, but in view of the general custom of teachers, and especially in view of some experiments recently published, the simpler formulæ are preferable and are adopted in the description below. Formulæ such as Al_2O_3, Fe_2O_3, cannot be divided, but are the same under both views.

ALUMINUM.

Aluminum, Al, 27, is abundant as silicate, constituting clay and many common rocks. Most building materials are mixtures of aluminum silicate with other silicates.

Aluminum is white and not very lustrous, malleable and ductile, sonorous and very light; specific gravity, 2.6. It tarnishes slightly in the air, and dissolves rapidly in hydrochloric acid and in sodium hydroxid, but not in nitric acid. It melts at 842° F. (450° C.). Valuable alloys of aluminum with copper, nickel, silver, etc., are now made by a process of electrical decomposition. The alloy of 90 parts of copper with 10 parts aluminum has the color of gold.

Aluminum forms but one series of compounds, which possess strong analogies to the higher series of iron salts; hence it is often regarded as forming compounds by the joint action of two tetrad atoms, which act as a hexad, but chemists are not unanimous on this point.

Aluminum Oxid, Al_2O_3, occurs naturally as *corundum*, which, when crushed, constitutes *emery;* finely crystallized, as the *ruby* and *sapphire*. It can be prepared by heating ammonium alum; it then forms a white powder.

In all the anhydrous forms it is absolutely insoluble in water, and almost so in acids and alkalies.

Aluminum Hydroxid, AlH_3O_3, is a gelatinous white mass, easily soluble in acids and alkalies. It has a strong affinity for organic matter; with organic colors it forms precipitates called lakes.

Aluminum Sulfate, $Al_2(SO_4)_3$, is now largely used in dyeing and in other operations. It forms a white crystalline mass having an acid reaction.

Alums.—The alums are a series of double sulfates. One alum has the formula—

$$Al_2(SO_4)_3 + K_2SO_4 + 24H_2O.$$

The aluminum in this compound may be replaced by most of the elements of the iron group. The potassium may be replaced by any element of its group, or by ammonium, giving a series of salts of which the following are examples:—

$Al_2(SO_4)_3$, K_2SO_4, $24H_2O$ . . . . . Potassium alum.
$Cr_2(SO_4)_3$, Na_2SO_4, $24H_2O$ . . . . . Sodiumchromic alum.
$Fe_2(SO_4)_3$, $(NH_4)_2SO_4$, $24H_2O$ . . . . . Ammoniumferric alum.

These compounds all contain the same amount of water of crystallization and all crystallize in octahedra. Bodies giving rise to compounds similar both in composition and in crystalline form are called *isomorphous.*

Common Alum is either potassium alum, or ammonium alum. It dissolves easily in water, the solution being acid to test paper and strongly astringent.

When alum crystals are gently heated they swell up, lose their water of crystallization, and fall to a soft white powder—burnt alum.

Aluminum Chlorid, $AlCl_3$, is prepared by heating alumina and charcoal in a current of chlorin:—

$$Al_2O_3 + 3C + 6Cl = 3CO + 2AlCl_3.$$

Glass, Pottery, and Porcelain.—These are mostly mixtures of aluminum, calcium, and sodium silicates. Colored glasses are produced by the use of various oxids.

Pottery and earthenware are made of clay, glazed with a fusible sodium silicate. Lead silicate is also used. Porcelain is a mixture of feldspar (aluminum and potassium silicate), sand, and *kaolin*, a hydrated aluminum silicate.

IRON.

Iron, Fe, 56, occurs as oxid, sulfid, and carbonate; its compounds occur *in small quantities in many* rocks and soils; it is taken up by plants; and is an essential constituent of the blood of the higher animals. It sometimes occurs native, especially in meteoric stones. A fine grade, Quevenne's iron, for use in medicine, is made by the action of hydrogen on the sesquioxid. On the large scale, iron ore, which generally consists of an oxid or carbonate mixed with clay, sand, and other minerals, is heated in blast-furnaces with coal and limestone. The limestone makes a fusible calcium silicate, *slag*; the coal takes the oxygen away from the iron. The melted mass is then run out into thick bars, forming *pig* or *cast iron*, containing four or more per cent. of carbon, also phosphorus, sulfur, silicon, and other bodies.

Wrought iron contains but little carbon; steel contains about one per cent. of carbon; it is, therefore, intermediate in composition. When pure, iron is very soft, but as found in commerce it has various impurities which give special qualities; carbon gives hardness and fusibility; phosphorus and sulfur give fusibility and great brittleness, and are objectionable. Cast iron melts at about 3000° F. (1649° C.). Iron is strongly magnetic and not much affected by dry air, but is oxidized by moist air and easily dissolved by acids. It forms two series of salts—*ferrous*, in which it is a dyad, and *ferric*, in which it is apparently a triad, but the formulæ of the ferric compounds are often doubled and the iron regarded as a double atom:—

Dyad Iron.	Hexad Iron.
$-\mathrm{Fe}-$	$\equiv\mathrm{Fe}-\mathrm{Fe}\equiv$

Ferrous salts are generally green; ferric salts brown or red.

Ferrous salts are converted into ferric by oxidizing agents. As the ferric salts are written with double formulæ, the reaction will always require two molecules of ferrous for one of ferric; thus:—

$$2\mathrm{FeO} + \mathrm{O} = \mathrm{Fe_2O_3}.$$
$$2\mathrm{FeCO_3} + \mathrm{O} = \mathrm{Fe_2O_3} + 2\mathrm{CO_2}.$$

To make a normal ferric salt we must add one-half as much of the negative element as the ferrous salt already contains; that is, one molecule of the radicle for every two molecules of the ferrous salt. In making ferric chlorid, the complete reaction is—

$$6\mathrm{FeCl_2} + 6\mathrm{HCl} + 2\mathrm{HNO_3} = 6\mathrm{FeCl_3} + 4\mathrm{H_2O} + 2\mathrm{NO}.$$

Ferrous salts are formed from ferric by the action of reducing agents, especially powdered zinc, nascent hydrogen, or sulfurous acid. With ferric chlorid and zinc the reaction is—

$$2\mathrm{FeCl_3} + \mathrm{Zn} = 2\mathrm{FeCl_2} + \mathrm{ZnCl_2}.$$

Hydrogen sulfid will also reduce ferric salts :—

$$2FeCl_3 + H_2S = 2FeCl_2 + 2HCl + S.$$

Ferrous Hydroxid.—Ferrous hydroxid, FeH_2O_2, is formed as a precipitate by the action of alkaline hydroxids upon a ferrous salt. It immediately begins to change by absorbing oxygen, and becomes ferric oxid.

Ferric Oxid, Fe_2O_3, *Red Oxid*, *Sesquioxid*, occurs frequently in small amounts in many minerals, and also as iron ore, called red hematite or specular iron. It may be prepared artificially by heating ferrous sulfate ($2FeSO_4 = 2Fe_2O_3 + SO_2 + SO_3$), and is the residue obtained in making Nordhausen sulfuric acid. It is a soft, red powder, difficult to dissolve in acids. The finer grades constitute *rouge;* the coarser, *venetian red* and *crocus*, are used for paints.

Ferric Hydroxid, $Fe_2H_6O_6$, is easily found by adding an alkaline hydroxid to a ferric salt :—

$$2FeCl_3 + 6KHO = 6KCl + 2FeH_3O_3.$$

Ferric hydroxid is a soft, brown mass, insoluble in water, but dissolving easily in acid. Its chief importance is as an antidote to arsenious oxid, for which use it must be freshly prepared. Ordinary iron rust consists of impure ferric hydroxid, which also occurs in an impure condition as brown hematite.

Magnetic Iron Oxid, FeO,Fe_2O_3, a union of the two oxids, is found as a finely crystallized mineral and valuable ore of iron. It can retain magnetism, and is occasionally found in a magnetized condition, constituting *loadstone.*

Ferrous Sulfid, FeS, made by fusing iron with sulfur, is a dark, slag-like mass, used as a source of hydrogen sulfid.

Iron Disulfid, FeS_2, *Iron Pyrites*, is abundant as a mineral, crystallized in brass-colored cubes often mistaken for gold, and hence called fool's gold. It is of no use as an iron ore, on account of the sulfur, but is used as a source of sulfuric acid.

Ferrous Carbonate is a valuable iron ore and exists in many (chalybeate) waters. It is produced by mixing ferrous sulfate with sodium carbonate :—

$$FeSO_4 + Na_2CO_3 = FeCO_3 + Na_2SO_4.$$

In this form, however, and also as dissolved in water, it is prone to oxidation, passing into the condition of ferric hydroxid, which forms a red deposit. This oxidation is hindered by sugar. Ferrous carbonate is prepared for medical use by precipitating it in contact with sugar, constituting Vallet's mass. The carbonate occurring naturally in the crystallized form is permanent in the air.

Ferrous Sulfate, $FeSO_4$, *Green Vitriol*, *Copperas*, is formed by dissolving iron in sulfuric acid or by oxidizing iron pyrites. It forms clear green crystals containing $FeSO_4,7H_2O$, easily soluble in water, the solution being liable to oxidation.

Ferric Sulfate.—An oxysulfate $(Fe_2)_2(SO_4)_5O$, called *Monsel's Salt*, or when dissolved *Monsel's Solution*, is used as a styptic.

Ferric Chlorid, $FeCl_3$, is generally seen as an alcoholic solution, sometimes called muriated tincture of iron. Ferric chlorid is made by boiling ferrous chlorid with nitric acid and hydrochloric acid:—

$$6FeCl_2 + 6HCl + 2HNO_3 = 6FeCl_3 + 4H_2O + 2NO.$$

When the solution is evaporated a red crystalline mass of $FeCl_3 + 3H_2O$ is formed, which is freely soluble in water and alcohol.

Ferrous salts are usually green, ferric red or brown.

The two classes of iron salts can be easily distinguished by certain tests:—

	With Ferrous Salts.	*With Ferric Salts.*
Ammonium hydroxid,	Green ferrous hydroxid, turning red,	Red ferric hydroxid.
Potassium ferrocyanid,	Light blue precipitate,	Dark blue precipitate.
Potassium ferricyanid,	Dark blue precipitate,	No precipitate.
Tannin,	No action,	Black precipitate.
Potassium thiocyanate,	No action,	Blood red color, but no precipitate.

MANGANESE.

Manganese, Mn, 55, exists principally as oxid, also as sulfid, carbonate, and silicate. It is grayish-white, brittle, and hard; specific gravity between 7 and 8. It forms two series of salts parallel to those of iron.

Manganous Oxid, MnO, and *Hydroxid*, MnH_2O_2, absorb oxygen rapidly.

Manganous Chlorid, $MnCl_2$, forms pink crystals, deliquescent and soluble in water.

Manganous Sulfate, $MnSO_4,7H_2O$, is a rose-colored salt, soluble in water, and used in dyeing.

Manganese Dioxid, MnO_2, *Black Oxid.*—This is an abundant mineral. It is extensively used as an oxidizing agent and in the manufacture of chlorin. Ordinarily it is in black masses or powder. It conducts electricity.

Manganese Oxid, Mn_2O_3, is found as a mineral. It is a weak base.

Manganese Acids.—Manganese furnishes two acids—

H_2MnO_4 . . . . Manganic acid.
$HMnO_4$ . . . . Permanganic acid.

The former has not been obtained, but some of its salts are known.

Manganates.—These are formed by fusing manganese dioxid with caustic alkali and potassium nitrate or chlorate. In this way potassium manganate, K_2MnO_4, is formed as a green crystalline mass. When dissolved in water the manganates turn into permanganates by the following reaction:—

$$3K_2MnO_4 + 2H_2O = 2KMnO_4 + MnO_2 + 4KHO.$$

The change of composition is indicated by a change of color from green to red.

Potassium Permanganate, $KMnO_4$, is much used as an oxidizing and deodorizing agent. The solution is decomposed by organic matters, by sulfites and sulfids and reducing agents generally, becoming converted into a colorless solution. It can therefore be employed not only to destroy organic matter, but also as an approximate measure of the amount present.

CHROMIUM.

Chromium, Cr, 52.2, occurs principally as an oxid in combination with iron oxid, constituting chrome iron ore, FeO,Cr_2O_3; also as lead chromate, $PbCrO_4$. It is a hard crystalline mass, not easily oxidized or dissolved. It forms two sets of salts, analogous to those of iron, and also anhydrids. The compounds in which it acts as a positive are of very little importance. The chromous salts are unstable. Almost all the chromium compounds are highly colored.

Chromic Oxid, Chromium Sesquioxid, Cr_2O_3, *Chrome Green*, is a bright green powder used as a paint.

Chromic Anhydrid, CrO_3, forms bright red crystals, very deliquescent, soluble in water, and having powerful oxidizing properties.

Potassium Chromate, K_2CrO_4, forms lemon-yellow crystals soluble in water.

Potassium Dichromate, $K_2Cr_2O_7$, commonly known as *bichromate*, is in large, bright red crystals soluble in water. It is extensively used as a source of various colors. It may be regarded as a salt of dichromic acid, $H_2Cr_2O_7$, produced by subtracting one molecule of water from two molecules of chromic acid:—

$$2H_2CrO_4 - H_2O = H_2Cr_2O_7.$$

Lead Chromate, Chrome Yellow, $PbCrO_4$, easily formed by adding a soluble chromate to a lead compound:—

$$Pb(NO_3)_2 + K_2CrO_4 = PbCrO_4 + 2KNO_3.$$

It is bright yellow and insoluble in water. Commercial chrome yellow often contains white lead and chalk.

A mixture of potassium dichromate and sulfuric acid is used as an oxidizing agent in galvanic batteries. The chromic acid becomes reduced and forms chromic sulfate; the liquid turns green, and afterward deposits dark ruby-red crystals of chrome-alum:—

$$K_2SO_4 + Cr_2(SO_4)_3 + 24H_2O.$$

Chromates are recognized by their color and the yellow precipitate of lead chromate formed when mixed with lead salts.

NICKEL.

Nickel, Ni, 59, occurs principally in union with arsenic and sulfur; also in meteoric iron as an alloy. It is hard and white, of specific gravity 8.8, fusing at a high temperature and resisting the action of air at common temperatures. Like iron, it can acquire permanent magnetism. Solutions of nickel compounds can be decomposed by an electric current, and nickel-plating is performed in this way. An alloy of copper, zinc, and nickel is called German silver.

Nickel Monoxid, NiO, and *Hydroxid,* NiH_2O_2, are green and form green salts.

Nickel Sesquioxid, Ni_2O_3, is also known, but does not appear to form salts.

Nickel Sulfate, $NiSO_4$, is the most important salt. It usually crystallizes with 7 molecules of water.

Cobalt, Co, 59, is found associated with nickel, which it closely resembles in properties and chemical relations. Its compounds are mostly red or blue. The element itself is hard, white, magnetic, and difficult to fuse; specific gravity, 8.7. The oxids, sulfates, carbonates, etc., resemble in composition those of nickel.

Nitrogen Group.—This includes boron, nitrogen, phosphorus, arsenum, antimony, bismuth, and gold, the first and last elements being not quite so marked in their relationship to the others. The members of the group are triads and pentads, sometimes apparently monads. Their oxids are either mostly acid anhydrids or in a few cases feeble bases. The group includes some of the most powerful mineral poisons known.

Many of the "ous" compounds of this group may be formulated so as to represent the elements as saturated pentads. Thus nitrous acid may be written: $H(\overset{v}{N}\overset{ii}{O}_2)$, that is hydrogen directly united to nitrogen. The conversion into nitric acid consists in the formation of hydroxyl, thus: $HO(\overset{v}{N}\overset{ii}{O}_2)$. Phosphorous acid may be written: $(HO)_2\overset{H}{P}O$, one H not being in the hydroxyl condition. Arsenous acid may also be so explained. The above suggestions agree very well with many of the reactions of the nitrites, phosphites, and arsenites.

BORON.

Boron, B, 11, is found in the form of Boric Acid, H_3BO_3, in steam jets in volcanic regions, and also as deposits of sodium or calcium borate. It has been obtained as a dark green powder, and in a crystalline form, resembling the diamond in hardness. Boron is a triad, and bears some resemblance in chemical functions to both carbon and aluminum.

Boric Acid, H_3BO_3, *Boracic Acid.*—This exists in the steam discharged in some volcanic regions, and some of its salts occur as minerals. It forms pearly scales of a bitter taste, soluble in water and alcohol and feebly acid. Heated to 248° F. (120° C.), it forms metaboric acid, HBO_2, and on still further heating it is converted into boric anhydrid, B_2O_3, which fuses to a clear glass. Its salts are called borates. Boric acid is an antiseptic. Several preparations of boric acid or of borates are now in the market as food preservatives. A mixture of boric acid and borax was at one time sold under the name of *rex magnus*. Such preparations are especially used for preserving milk. A compound prepared by the incorporation of boric acid with glycerol, known as boro-glycerid, is also employed as a preservative.

Boric acid has a feeble action on litmus, and turns turmeric paper to a brown-red color. It imparts a bright green color to flame.

Borax, $Na_2B_4O_7$, sometimes called sodium biborate, is the most familiar compound of boron, and may be regarded as sodium tetraborate. Tetraboric acid is not known in the free state, but can be theoretically derived by subtracting one molecule of water from four molecules of metaboric acid:—

$$4HBO_2 - H_2O = H_2B_4O_7.$$

Borax has the power to take up oxids and re-form metaborates, and, as the compounds are fusible at moderate heat, borax is frequently used in metallurgical operations (*e.g.*, soldering) to clean off the surfaces of metals, which it does by dissolving the oxids.

NITROGEN.

Nitrogen, N, 14, constitutes about four-fifths of air, and occurs in many animal and vegetable tissues; also as sodium and potassium nitrates.

It is a gas without color, taste, or smell. It does not burn or support combustion, and is not poisonous, but will not support life. At high temperature, and under the influence of electric discharges, it will enter into combination with oxygen, boron, silicon, carbon, hydrogen, and magnesium. It is a little lighter than air; a litre weighs 1.25 grms. It can be liquefied by intense cold and pressure. There is probably an allotropic form.

Nitrogen is generally a pentad; sometimes it acts as a triad, or even as a monad. It is an essential ingredient of all the higher tissues of animals, and exists also in vegetable structures, but not so abundantly. Most of the powerful explosives now in use—gun-cotton and nitroglycerol, for instance—owe their qualities largely to the nitrogen present.

Air.—The atmosphere is an intimate *mixture* of about four volumes of nitrogen with one volume of oxygen. It surrounds the earth to the height of many miles. Air is dissolved by water, but the nitrogen and oxygen are in proportion different from that in ordinary air. The composition is not absolutely constant nor in exact atomic proportions, either by weight or volume.

That the composition of air varies so little is due to the fact that all gases mingle with one another, so that sooner or later they produce a uniform mixture in spite of the influence of gravity. The rate of mixture depends on the density of the gas.

Ordinary air contains small quantities of other substances besides nitrogen and oxygen. It always contains water, carbonic acid, and amin; frequently compounds of nitrogen and oxygen, and also ozone. Besides these we have dust and the products of animal and vegetable decomposition. The study of impurities of air has received much attention of late years, especially in view of the fact that many diseases are due to living organisms, or germs which are conveyed in the air.

The following may be taken as a fair average of composition:—

Oxygen, ...	20.61
Nitrogen, ...	77.95
Carbon dioxid, . .	.03
Water, ...	1.40

Traces of amin, nitric acid, and methane (CH_4), and in towns, sulfur compounds.

100 cubic inches of air weigh 30.93 grains; 1 litre weighs 1.29 grammes; 13 cubic feet weigh about 1 lb. At the level of the sea the pressure is, ordinarily, about 15 lbs., and will sustain a column of mercury 760 millimetres, or 30 inches, in height. Water in its natural condition always contains some air in solution.

The capacity of air for holding moisture increases rapidly as the temperature rises. The dryness or dampness of the atmosphere is not due to the actual quantity of moisture in it, but to the amount present in proportion to that which the air can take up. The nearness of air to saturation is called the *relative humidity.* Air saturated with water has a relative humidity of 100; if half saturated, the relative humidity is 50, and so on. When the temperature falls the moisture separates to a greater or less extent, and produces fog, rain, or dew, and if the temperature gets below the freezing point, snow or frost.

The respiration of animals and the processes of combination and decay are continually changing the air, by removing oxygen and introducing water, carbonic acid, organic matter, ammonia, and hydrogen sulfid. The dust which is always floating in the air contains substances living and dead, and varies with the locality. The continued removal of oxygen is counterbalanced by the action of plants, which, under the influence of light, decompose the carbonic acid, retaining the carbon and giving off the oxygen, especially at the under surface of the leaves. Plants also absorb oxygen and excrete carbon dioxid continuously; this process not depending on light. The nitrogen of the atmosphere is very little affected in these actions. The amin and other gases are gradually oxidized or absorbed by the soil and plants and washed out by the rains. The organic matter is also oxidized.

Amin, NH_3, *Ammonia Gas*, *Ammonia.*—Amin is given off in the decomposition of organic matter, especially animal remains, and was originally derived from refuse of this kind. It is also produced by the action of hydrogen on nitric acid. The great source at the present time is the water which has been used for washing the common illuminating gas. Amin may be obtained by heating a mixture of ammonium chlorid (NH_4Cl) and lime:—

$$2NH_4Cl + CaO = 2NH_3 + H_2O + CaCl_2.$$

By passing the gas over dry lime the water is absorbed and the pure NH_3 is collected.

Amin is a colorless gas of a pungent odor. It is absorbed in large amounts by water, one pint absorbing 700 pints of gas and increasing fifty per cent. in volume. This solution exhibits most of the properties of the gas, and is much used under the name of *aqua ammoniæ* or solution of ammonia.

Amin is lighter than air. 1 litre weighs 0.76 grm. At a temperature of −40° F. (—40° C.), or under a pressure of 100 lbs. to the square inch, it condenses to a colorless liquid. This liquid, of course, evaporates rapidly when the pressure is removed, and produces great cold, which fact has been made use of in machines for making ice.

The solution of amin in water has strongly alkaline and basic powers, much like those of potassium and sodium hydroxids. It has received the name of *volatile alkali*, to indicate this, the others being called fixed alkalies. The compounds produced by it may be considered as formed in the same manner as those of potassium and sodium, these elements being represented by the radicle, NH_4. In this way $NH_3 + HCl$ would produce NH_4Cl; $NH_3 + H_2O$ would produce NH_4HO. NH_4 is a radicle called *ammonium*; its valency is one; it combines with one atom of chlorin and can replace the hydrogen of acids.

The following formulæ show the comparison between the salts of potassium and those of ammonium:—

KCl	Potassium chlorid.
NH_4Cl	Ammonium chlorid.
K_2SO_4	Potassium sulfate.
$(NH_4)_2SO_4$	Ammonium sulfate.
KNO_3	Potassium nitrate.
NH_4NO_3	Ammonium nitrate.
KHO	Potassium hydroxid.
NH_4HO	Ammonium hydroxid.

Ammonium, NH_4, has not been obtained in the free state.

Ammonium Hydroxid, NH_4HO, the result of the solution of amin in water, is a colorless liquid, corrosive, poisonous, powerfully alkaline, and pungent.

Ammonium Carbonate, $(NH_4)_2CO_3$, is not generally seen. The body sold as ammonium carbonate is a mixture of acid ammonium carbonate with ammonium amido-carbonate (see under amido-compounds), therefore, $NH_4HCO_3 + NH_4\,(NH_2CO_2)$. It is often called sesquicarbonate, or smelling-salt.

It is a white body, soluble in water, and smelling strongly of amin. By exposure to air it is converted into acid carbonate, NH_4HCO_3.

Ammonium Nitrate, NH_4NO_3, is a white solid, very soluble in water. Its chief use is for making nitrous oxid.

Ammonium Sulfate, $(NH_4)_2SO_4$, is used as a fertilizer and in the manufacture of alum.

Ammonium Chlorid, *Sal Ammoniac*, NH_4Cl, is a white solid, crystallizing in cubes, and is very soluble in water. It has many uses.

Ammonium Bromid, NH_4Br, *Ammonium Iodid*, NH_4I, are used in photography and medicine.

If dry ammonium compounds be heated with lime, amin is quickly evolved, and may be recognized by its odor, alkaline reaction, and the white cloud of NH_4Cl produced by hydrochloric acid. The most delicate test for ammonium is Nessler's reagent, a solution made by mixing $HgCl_2$, KI, and KHO or NaHO. This produces, with very minute quantities of ammonium, a yellow color. One part in fifty million parts of water can be recognized.

Nitrogen Oxids.—Five compounds of nitrogen and oxygen have been obtained :—

N_2O	Nitrous oxid, laughing gas.
NO	Nitric oxid (often written N_2O_2).
N_2O_3	Nitrous anhydrid.
NO_2	Nitrogen dioxid (often written N_2O_4).
N_2O_5	Nitric anhydrid.

The names of these compounds are confused. Thus, NO is often written N_2O_2, and called nitrogen dioxid. NO_2 is written N_2O_4, and called nitrogen tetroxide.

Nitric Acid, *Aqua fortis*, HNO_3, is made by the action of strong sulfuric acid upon nitrates. The reaction with sodium nitrate is—

$$2NaNO_3 + H_2SO_4 = NaSO_4 + 2HNO_3.$$

Nitric acid thus obtained has the composition HNO_3; when quite pure it is colorless. The commercial acid has the composition of $2H_2O + HNO_3$. It is a strongly acid liquid, highly corrosive and poisonous and of high oxidizing power. One-half the oxygen of the acid is available. The effect is in most cases represented thus :—

$$2HNO_3 \text{ decomposes into } H_2O + 2NO + O_3.$$

The O_3 is the available oxygen. With some bodies the acid acts simply by exchanging its hydrogen. Thus:—

$$Zn + 2HNO_3 = Zn(NO_3)_2 + H_2.$$

The evolved hydrogen, however, attacks another portion of nitric acid and forms ammonium nitrate.

If basic oxids are formed by the oxidizing action of nitric acid, they will unite with another portion of the acid to form nitrates. In the case of copper, the following reactions take place:—

Oxidation of the copper occurs first—

$$Cu_3 + 2HNO_3 = 3CuO + H_2O + 2NO.$$

The CuO then acts upon other nitric acid—

$$2CuO + 6HNO_3 = 3Cu(NO_3)_2 + 3H_2O.$$

The complete reaction is, therefore—

$$3Cu + 8HNO_3 = 3Cu(NO_3)_2 + 4H_2O + 2NO.$$

Tin gives the following:—

$$Sn_3 + 4HNO_3 = 3SnO_2 + 2H_2O + 4NO.$$

SnO_2 is not basic, and therefore does not form a nitrate, as copper oxid would. Instead of this, the tin dioxid takes water and forms an acid. Many organic bodies are oxidized by nitric acid.

Another action of nitric acid is in forming substitution compounds. When benzene, C_6H_6, is treated with strong nitric acid, one atom of hydrogen is received and one molecule of NO_2 put in its place. We have—

$$C_6H_6 + HNO_3 = C_6H_5(NO_2) + H_2O,$$

and the body so formed is called *Nitrobenzene.*

A mixture of nitric and sulfuric acids is often used for such effects.

Very strong nitric acid fails to act upon some substances which are readily attacked by the more dilute forms.

The strong acid produces yellow stains on organic matter.

Nitric acid colors morphin red; copper is dissolved by it, with the production of red fumes of NO_2.

Nitrous Oxid, N_2O, *laughing gas,* sometimes called *nitrogen monoxid,* is obtained from ammonium nitrate, which, when carefully heated, decomposes completely into nitrous oxid and water:—

$$NH_4NO_3 = NO_2 + 2H_2O.$$

It is a colorless, odorless gas, with a somewhat sweetish taste. When the gas is inhaled freely, a short insensibility is produced. It supports combustion. At a pressure of fifty atmospheres it becomes a colorless liquid, and is now sold in this form compressed in strong metal cylinders. Nitrous oxid may be regarded as the anhydrid of hyponitrous acid, HNO, several derivatives of which have been described.

Nitric Oxid, NO, often called nitrogen dioxid and written N_2O_2, is a frequent product of the action of nitric acid. Thus, with copper we have—

$$Cu_2 + 8HNO_2 = 3Cu(NO_3)_2 + 4H_2O + 2NO.$$

Some N_2O is often produced in this experiment.

NO is a colorless gas, but when brought in contact with oxygen it instantly absorbs one atom, becoming NO_2 and turning brownish-red.

Nitrogen Dioxid, NO_2, *Nitrogen Peroxid.*—These names are owing to uncertainty in the chemical relations of the body. It has also been called nitrogen tetroxid (being written N_2O_4) and hyponitric acid, and by other less common names. The proper name is nitrogen dioxid, to correspond to the formula NO_2. It is a brownish-red gas, easily condensed to the liquid form and readily absorbed by water.

Nitrous anhydrid, N_2O_3, and nitric anhydrid, N_2O_5, are unimportant, as is also nitrous acid, HNO_2. Nitrites are frequently found in river and well water.

PHOSPHORUS.

Phosphorus, P, 31, occurs principally as calcium phosphate, which exists in bones and teeth, and in many minerals. Phosphates also exist in the fluids of the animal body.

Phosphorus is generally prepared from bones, which contain from one-third to two-thirds their weight of calcium phosphate. The bones are burned, and from the *bone ash* the phosphorus is obtained.

Phosphorus is usually seen in colorless, almost transparent sticks, soft as wax; when kept for some time, especially in the light, it becomes brownish, opaque, and harder. It is kept under water. It takes fire easily, and burns with a bright flame, producing white clouds of phosphoric anhydrid, P_2O_5. Exposed to air at low temperature, it can still undergo a slow combustion, producing P_2O_3; it is then luminous in the dark. It is insoluble in water, but dissolves in oils and in carbon disulfid. It is extremely poisonous, death having occurred from less than $\frac{1}{4}$ grain. Phosphorus melts at 111° F. (43° C.), and boils at 550° F. (288° C.). By keeping it at a temperature of 450° F. (232° C.) for some hours, in a closed vessel, phosphorus is converted into the *amorphous* or *red phosphorus*, an allotropic form, which is red, insoluble in carbon disulfid, difficult to burn, non-poisonous, and shows many other minor differences. Its composition is the same. This change is also produced by adding a small quantity of iodin to common phosphorus. The uses of the element in matches and as a medicinal substance are well known.

In all experiments with it great care must be taken, as it is easily inflamed and produces one of the most severe forms of burns known. It should be handled with a pair of forceps, and cut or divided only under water.

Phosphorus acts as a triad or pentad; its affinities in the free state are very high. It is a powerful reducing agent. In very minute quantity it is detected by its luminosity when distilled in a dark room.

Hydrogen Phosphid, PH_2, *Phosphin.*—This body is formed under conditions analogous to those which produce amin. When a solution of sodium hydroxid is boiled with phosphorus, hydrogen phosphid is formed.

The reaction is—

$$3NaHO + 3H_2O + P_4 = 3NaH_2PO_2 + PH_3.$$

NaH_2PO_2 is sodium hypophosphite. Hydrogen phosphid is a colorless gas of a disagreeable odor. As ordinarily made it is spontaneously inflammable, but this is due to the presence of a small quantity of the vapor of a liquid phosphid, PH_2, phosphidogen. If this latter be removed by passing the fresh gas through a tube placed in a freezing apparatus, the power of spontaneously inflaming is lost.

Hydrogen phosphid forms many compounds analogous to those formed by amin.

Compounds of Phosphorus with Oxygen.—Only two compounds are definitely known. These are:—

P_2O_3 . . . . Phosphorous anhydrid or phosphorous oxid.
P_2O_5 . . . . Phosphoric anhydrid or phosphoric oxid.

Phosphorous Anhydrid, P_2O_3, is produced by the slow oxidation of phosphorus.

Phosphoric Anhydrid, P_2O_5.—This is easily produced by burning phosphorus in the air. It is a snow-like solid, which rapidly absorbs water. It is capable of uniting with water in at least three proportions, forming different bodies. The combination is shown in the following equations:—

$P_2O_5 + H_2O = 2HPO_3$ . . . . Metaphosphoric acid.
$P_2O_5 + 2H_2O = H_4P_2O_7$ . . . . Pyropnosphoric "
$P_2O_5 + 3H_2O = 2H_3PO_4$ . . . . Orthophosphoric "

The third acid is the one that yields all the common phosphates.

Metaphosphoric acid is distinguished by the power of coagulating albumin. Although the three phosphoric acids differ in oxygen, the termination " ic " is not changed. This is because they are all formed from the same anhydrid; the difference in oxygen is due to the amount of water, and all contain pentad phosphorus. The number of salts formed by each acid is in proportion to the number of molecules of water which it has taken up.

Metaphosphoric acid, produced by adding *one* molecule of water, gives *one* series of salts :—

$NaPO_3$	Sodium metaphosphate.
$Ca(PO_3)_2$	Calcium "

Pyrophosphoric acid, produced by adding *two* molecules of water, gives *two* series of salts, acid and normal :—

$Na_2H_2P_2O_7$	Acid sodium pyrophosphate.
$Na_4P_2O_7$	Sodium "

Orthophosphoric acid, produced by adding *three* molecules of water, gives *three* series of salts, di-acid, acid, and normal :—

NaH_2PO_4	Di-acid sodium orthophosphate.
Na_2HPO_4	Acid " "
Na_3PO_4	Sodium orthophosphate.

Sodium, potassium, and ammonium phosphates are mostly soluble in water. Almost all others are insoluble in water, but soluble in acids.

Silver nitrate produces with orthophosphates a yellow precipitate soluble in ammonium hydroxid. A solution of ammonium molybdate in nitric acid gives a bright yellow precipitate. This is a very delicate test.

Two phosphorus chlorids are known, PCl_3 and PCl_5.

ARSENUM.

Arsenum, As, 75, occurs in the free state and as sulfid, also in combination, especially with nickel, cobalt, and iron. It is rather abundant, and exists in small amounts in many minerals. It is often called arsenic, but arsenum is a preferable name.

It is prepared by deoxidizing arsenous anhydrid by charcoal :—

$$As_2O_3 + C_3 = As_2 + 3CO.$$

When freshly prepared it is a steel-gray, brittle mass with a decided lustre.

It tarnishes somewhat in the air, and passes into vapor at about 356° F. (180° C.) without fusing. Heated in contact with air, it oxidizes to arsenous anhydrid, and develops a garlicky odor. It is not dissolved by any simple solvent.

Arsin, AsH_3, *Hydrogen Arsenid.*—This body is analogous to amin; its formation is a delicate test for arsenic. The usual method of preparation is to liberate hydrogen in a solution of arsenous anhydrid. It is a combustible gas of disagreeable odor and very poisonous.

Compounds of Arsenum with Oxygen :—

As_2O_3 . . . . . Arsenous oxid or arsenous anhydrid.
As_2O_5 . . . . . Arsenic " " "

Arsenous Anhydrid, As_2O_3, *Arsenous Oxid, White Arsenic.*—This substance is often called arsenic. It presents itself in commerce in two varieties: (*a*) The vitreous form, transparent and colorless at first, but afterward becoming yellowish and porcelain like; (*b*) A pulverulent form, which is distinctly crystalline.

Arsenous oxid is a white solid, odorless and tasteless, dissolving with difficulty and only in small amounts in cold water; the solution is feebly acid, and is supposed to contain arsenous acid, H_3AsO_3. Hot water is a more active solvent. A fluidounce of cold water will dissolve about one grain, and the same amount of water if kept for one hour at the boiling-point will take up at least twelve grains. In acid and alkaline solutions it dissolves much more readily. Heated to 380° F. (190° C.), the solid passes into vapor without fusing, and if allowed to condense produces brilliant, transparent crystals. It is intensely poisonous in all its forms, a few grains being a fatal dose. Arsenous oxid is used in medicine, also in the manufacture of colors, and for many other purposes. Its frequent occurrence and poisonous qualities have made its properties and tests of great importance. The following is a brief summary of the methods used :—

1. *Reduction Test.*—A small quantity of powdered arsenous oxid is mixed with some dried potassium ferrocyanid and heated in a narrow glass tube. Arsenum is set free, rises in vapor, and condenses on a cooler portion of the tube, as a dark steel-gray but rather lustrous layer, called the *arsenical mirror.* If this deposit be heated, it may be driven further along the tube, and will finally oxidize and produce the garlicky odor.

2. *Sublimation Test.*—Arsenous oxid heated alone passes quickly into vapor, and by allowing this vapor to condense upon a *slightly warmed* part of the tube fine crystals are formed. Under the microscope these crystals are seen

to be octahedral; that is, consist of eight triangular faces, though they are rarely completely formed. Very minute quantities of arsenic can be recognized by this test.

3. *Reinsch's Test.*—This is the most valuable test, because it can be applied to impure mixtures, as the contents of a stomach. A small quantity of water is put into a wide test-tube or porcelain basin; some hydrochloric acid is added; a piece of clean copper is put in and the water brought to boiling. A few drops of the suspected solution are now added, and if an arsenum compound be present a dull, steel-colored deposit of copper arsenid will soon form on the copper. When this deposit has become rather dense, the copper is taken out, dried with filter paper, rolled up into small bulk, and placed in the end of a small glass tube. Heat being applied, the deposit is oxidized and volatilized, forming octahedral crystals of arsenous oxid.

4. *Marsh's Test.*—This depends on the power of nascent hydrogen to form arsin, AsH_3. The hydrogen is obtained either by the action of sulfuric acid upon zinc or magnesium, of sodium amalgam on water, or by a current of electricity. Arsin is combustible. If a cold porcelain plate be held in the flame, a soot of arsenum will be deposited as a brown, shining stain. If the tube which is conducting the current be heated, the gas will be decomposed and a similar stain formed within the tube. The stains may be identified by the fact that they are: (*a*) easily volatile; (*b*) soluble in a solution of bleaching powder; (*c*) capable of producing octahedral crystals of arsenous oxid.

Three tests, known as the liquid tests, are applicable only to pure solutions of arsenous oxid. They are—

1. Hydrogen sulfid produces a lemon-yellow precipitate of arsenous sulfid, As_2S_3:—

$$As_2O_3 + 3H_2S = As_2S_3 + 3H_2O.$$

A few drops of hydrochloric acid facilitate the action.

2. Silver nitrate made feebly alkaline by ammonium hydroxid gives a yellow precipitate of silver arsenite.

3. Copper sulfate, made feebly alkaline, gives a green precipitate of copper arsenite.

Arsenic Oxid, As_2O_5.—This is produced by oxidizing arsenous oxid with nitric acid. It forms with water arsenic acid, H_3AsO_4, which is used as an oxidizing agent in the manufacture of anilin colors. This use has been supposed to account for the cases of skin irritation which have been occasionally observed to follow the wearing of goods dyed with these colors, but it is *doubtful if any of the poison* ordinarily remains in the manufactured fabric.

Arsenic acid forms salts called arsenates. Three forms of arsenic acid are known, corresponding to the three forms of phosphoric acid.

Compounds of Arsenum and Sulfur.—Three of these are known :—

AsS	Arsenum monosulfid, *realgar.*
As_2S_3	Arsenous sulfid, *orpiment.*
As_2S_5	Arsenic “

Realgar is a brick-red solid, easy volatile. It may be considered as analogous to NO. It is often written as As_2S_2.

Orpiment, King's yellow, is found as a mineral and is easily produced artificially by the action of hydrogen sulfid upon arsenous compounds.

It is a bright yellow solid, fusible and volatile, soluble in alkalies, but insoluble in water and dilute acids. It is often obtained in the process of testing for arsenic, and in the arts is used as a pigment.

Arsenum forms chlorids, bromids, and iodids, but they need not be described.

ANTIMONY.

Antimony, Sb, 122, occurs sometimes in the free state, but generally as sulfid, Sb_2S_3. It is also called *Stibium.*

Antimony is bluish-white, brittle, generally highly crystalline and of brilliant lustre. It fuses at 842° F. (450° C.), and volatilizes at a red heat. On cooling from the melted condition it expands somewhat, and some of its alloys retain this property, for which reason it is used in type metal and other alloys which must take sharp casts. Like arsenum, it is not soluble in any simple solvent.

The chemical relations of antimony are much like those of arsenum, phosphorus, and nitrogen. It forms an oxid which is slightly basic.

Antimony is detected by tests similar to those of arsenum. The distinctive differences are :—

1. The sublimate of free antimony cannot be obtained by the reduction test unless a very high temperature be used.

2. Antimonous oxid cannot be volatilized except by a high heat, and does not usually form octahedral crystals, but these have been obtained under certain conditions.

3. The copper slip in Reinsch's test becomes covered with a bluish or violet deposit, which gives a sublimate only with great difficulty.

4. In Marsh's test a much darker spot is obtained; it is volatilized with difficulty, and not dissolved by a solution of bleaching powder.

5. The liquid tests give no result, except with hydrogen sulfid, which produces an *orange-red* precipitate.

Stibin, Hydrogen Antimonid, SbH_3, resembles the corresponding arsenic compound, and is produced under similar conditions. It has not been obtained pure.

Compounds of Antimony with Oxygen.—These are:—

Sb_2O_3 . . . . . . Antimonous oxid, or anhydrid.
Sb_2O_5 . . . . . . Antimonic " "

An intermediate oxid, Sb_2O_4, probably a mixture of the other two, is known.

Antimonous Oxid, Sb_2O_3.—This is found as a mineral, and is also readily prepared by burning antimony in the air. It is like As_2O_3 in many of its chemical relations, but is insoluble in water, less volatile, and shows some power of combining with acids to form salts. When boiled with a solution of cream of tartar (acid potassium tartrate) antimonous oxid loses one atom of oxygen, and dissolves, forming *tartar emetic,* potassium antimonyl tartrate. This compound is the most familiar preparation of antimony, as it dissolves in water without decomposition. The reaction in its production is:—

$$2KHC_4H_4O_6 + Sb_2O_3 = 2K(SbO)C_4H_4O_6 + H_2O.$$

The SbO replaces the hydrogen.

Boron or arsenum may take the place of antimony in this compound.

Antimonic Oxid, Sb_2O_5, forms two acids corresponding to the meta- and pyrophosphoric acids: $HSbO_3$, metantimonic, and $H_4Sb_2O_7$, pyrantimonic acid. Pyrantimonic acid is remarkable for forming a sodium compound insoluble in water.

Antimony forms compounds with chlorin, bromin and iodin analogous to those of phosphorus and arsenic. They are mostly decomposed when mixed with large quantities of water, yielding at first an impure, finally a pure, oxid. With antimonous chlorid we have—

$$3SbCl_3 + 3H_2O = SbCl_3Sb_2O_3 + 6HCl.$$

The oxychlorid, $SbCl_3Sb_2O_3$, becomes finally converted into pure antimonous oxid.

Antimony Sulfids.—Two are known:—

Sb_2S_3 . . . . Antimonous sulfid.
Sb_2S_5 . . . . Antimonic sulfid.

Antimonous Sulfid is the principal ore of antimony. It is found as a *shining, gray, crystalline mass,* fusible and easily oxidized by heating in the air.

Hydrochloric acid dissolves it easily, forming antimonous chlorid and hydrogen sulfid:—

$$Sb_2S_3 + 6HCl = 2SbCl_3 + 3H_2S.$$

On the other hand, a current of hydrogen sulfid passed into antimony solutions produces the antimonous sulfid as an *orange-red* precipitate, which by heating becomes like the natural form.

Antimonic Sulfid is an orange-yellow body.

The chemical relations of antimony are well shown in its sulfids. Both of them act as anhydrids, and form a series of salts.

$KSbS_2$ . . . . Potassium sulfantimonite

is strictly comparable to

KNO_2 . . . . Potassium nitrite.

Antimonic sulfid forms salts upon the pattern of the orthophosphates.

Na_3SbS_4 . . . . Sodium sulfantimonate

is analogous to

Na_3PO_4 . . . . Sodium orthophosphate.

Sodium sulfantimonate has been used in photography under the name of *Schlippe's salt.*

BISMUTH.

Bismuth, Bi, 208, is commonly found native; also as oxid and sulfid.

It is hard, brittle, reddish-white, and distinctly crystalline. It fuses at 507° F. (264° C.), expanding when it solidifies. It is not much affected by the air. Nitric acid dissolves it.

Bismuth Sesquioxid, Bi_2O_3, the only important oxid, is obtained as a yellowish powder by burning bismuth in the air or by heating the carbonate or nitrate. It acts as a base.

Bismuth Nitrate, $Bi(NO_3)_3$, made by dissolving bismuth in nitric acid, is a soluble, white, crystalline mass. When added to a large volume of water, a white precipitate of bismuth oxynitrate, of irregular composition, but generally $BiNO_3O$, is thrown down. This powder, ordinarily called *bismuth subnitrate*, is used in medicine and sometimes as a cosmetic. When it is boiled with sodium hydroxid and a solution of glucose, a heavy black powder of free bismuth is formed. This is Boettger's test for sugar.

Bismuth Chlorid, $BiCl_3$, is decomposed by water in a manner similar to the nitrate, producing an oxychlorid.

Bismuth Subcarbonate, a compound of irregular composition, is used in medicine.

GOLD.

Gold, Au, 196.7, occurs in the free state, often in veins in quartz, often in small grains in sand and gravel; sometimes alloyed with silver, copper, or other bodies.

Pure gold is very heavy (specific gravity, 19.4), capable of being worked into thin plates or wire, and an excellent conductor of heat and electricity. The ordinary yellow appearance is due to much admixed white light. The true color, red, is obtained by repeated reflections. It melts at 1900° F. (1036° C.). It is unaffected by air, water, sulfur, or ordinary acids, even at high temperatures. Its compounds are reduced by heat, and by reducing agents in the cold. Chlorin or a mixture of nitric and hydrochloric acid (which contains free chlorin) dissolves it, forming a chlorid. In the pure condition it is very soft and can be welded in the cold by pressure. Gold-foil is prepared in this form for dentists' use. For articles subjected to wear it is alloyed with copper or silver. The proportion of alloy is indicated by *carats*, pure gold being 24 carats, 18-carat gold being 18 parts gold and 6 parts alloy. Copper makes a red alloy; silver, a green alloy. The United States coin gold contains 90 per cent. of gold alloyed with copper and silver. Two sets of compounds are known, aurous and auric, in which the metal is respectively a monad and a triad. The oxids are not bases; one appears to be an anhydrid.

Au_2O . .	Aurous oxid.
Au_2O_3 . .	Auric "
$AuCl$ . .	Aurous chlorid.
$AuCl_3$ . .	Auric "

Auric Chlorid is produced when gold is dissolved in nitro-muriatic acid. By adding to the liquid, free from excess of acid, some ferrous sulfate, the gold is thrown down as a brown powder. A mixture of stannous and stannic chlorids produces with gold chlorid a purple precipitate, called *purple of Cassius*, used for coloring glass and porcelain.

Vanadium, V, 51.3, is a rare body, found chiefly in combination with iron and lead. It forms four oxids. VO, V_2O_3, VO_2, V_2O_5.

Vanadic Anhydrid, V_2O_5, forms salts called vanadates. Lead vanadate is found as a mineral. It yields compounds analogous to metaphosphoric acid, and also forms salts with some of the strong acids. Vanadium has acquired some importance from the possibility of making from it a good indelible ink, but the rarity of its compounds has interfered with this use.

Carbon Group.—This includes carbon, silicon, tin, and titanium. They are positive tetrads. With the exception of carbon and silicon they form feebly basic oxids. All of them form acid anhydrids. Platinum may also be placed in this group.

CARBON.

Carbon, C, 12, occurs very abundantly in nature. It is so constant a component of organic bodies that organic chemistry has been called the chemistry of the carbon compounds. In the tissues of animals and plants it exists in union with hydrogen, oxygen, and nitrogen. The various forms of coal and graphite, and certain carbonates, especially of calcium and magnesium, are abundant minerals. Carbon presents itself under several allotropic forms.

Amorphous Carbon, such as lampblack and charcoal.

Graphite, or *Plumbago*, a crystalline form.

Diamond, also crystalline, often chemically pure.

These forms are insoluble in all ordinary liquids, infusible and unacted upon by acids and alkalies or by the air at ordinary temperatures. Heated strongly in air or oxygen, they burn, producing CO or CO_2.

Lampblack is the deposit from smoky flames. It generally contains hydrogen.

Wood charcoal contains hydrogen and the mineral substances of the wood.

Animal charcoal is obtained by charring animal tissues.

Wood and animal charcoals have great powers of absorption—the former for gases, the latter for organic matters, especially colors and bitter principles.

This property of wood charcoal explains its use as a deodorizer. Gases containing hydrogen, sulfur, or phosphorus are generally entirely decomposed when absorbed by charcoal.

If a solution of some organic color, such as litmus or cochineal, be filtered through animal charcoal, the color will be partly or wholly removed. Bitter principles, such as strychnin or the bitter of hops, will also be removed. Animal charcoal is extensively used for the decolorization of syrups and vegetable infusions generally.

Graphite, called also plumbago and black lead, is destitute of any absorbent properties, and is used for lead-pencils and for crucibles.

Diamond is a crystalline form of carbon. It is the hardest substance known, and has been used with great advantage for the drilling and cutting of stone.

The specific gravity, color, and hardness are different in the various forms of carbon.

Coal has been formed from organic matter. Bituminous or soft coals are first produced. They contain hydrogen and oxygen. Coke is the residue after heating the coal. Anthracite coal is much harder, and has very little hydrogen. It yields no gas on heating.

Carbon is a tetrad; and combines with many elements.

Compounds of Carbon with Hydrogen.—Hydrogen and carbon combine in many proportions.

Coal Gas.—When bituminous coal is heated in a closed vessel, a large amount of gas is given off. This gas, after being purified, constitutes illuminating gas—a mixture of hydrogen, methane, CH_4, ethene, C_2H_4, and other gases.

Compounds of Carbon with Oxygen. The important ones are—

Carbon monoxid, ...	CO.
Carbon dioxid, . .	CO_2.
Carbonic anhydrid,	

Carbon Monoxid, Carbonic Oxid, CO.—This is produced when carbon is burned in a deficient supply of air, as in stoves with defective draft and in the large furnaces for reducing and working iron, in which an excess of fuel is purposely maintained. When steam is thrown upon hot coal a mixture of carbon monoxid and hydrogen, generally called water-gas, is produced. This is available as a gaseous fuel, or may be impregnated with vapors of gasoline and used as a source of light. For experimental purposes the action of sulfuric acid upon oxalic acid or upon potassium ferrocyanid is used for the preparation of CO.

Carbon monoxid is a colorless, odorless, tasteless gas, of decidedly narcotic poisonous properties. It is a little lighter than air. It burns easily with a clear blue flame. It is an unsaturated molecule, and will combine with chlorin and some other elements. By reason of its unsaturated condition, it has the power to unite firmly with hemoglobin, and prevent the proper oxidation of the blood, thus producing, when inhaled, a persistent asphyxiated condition. Poisoning by carbon monoxid has now become of common occurrence in consequence of the extended use of water-gas. It is not unlikely that the unnoticed escape of this gas in houses is the cause of much discomfort and ill health.

Carbon Dioxid, Carbonic Anhydrid, CO_2, often wrongly called carbonic acid, is an abundant substance occurring in air and water. Some of its compounds, especially calcium and magnesium carbonates, are common minerals. Carbon dioxid is produced in a great variety of ways:—

1. By the respiration of animals;
2. By ordinary combustion;
3. By fermentation and decay;
4. By decomposition of carbonates, either by heat or by acids.

The reaction in the case of chalk and hydrochloric acid is—

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2.$$

It is unimportant whether we regard the water and CO_2 as separate or united to form carbonic acid, H_2CO_3. By passing the escaping gas over dry calcium chlorid or strong sulfuric acid the pure CO_2 may be collected.

Properties.—Carbon dioxid is a colorless gas of a somewhat sharp taste. It is soluble at ordinary pressure in its own bulk of water, and the solubility is increased in proportion to the pressure. It is about fifty per cent. heavier than air. 1 litre weighs 2.07 grms. It can be liquefied by a pressure of 550 lbs. to the inch, and freezes at —70° F. (—56° C.). It does not support animal life nor ordinary combustion; but bodies of high affinity, if already in active combustion, will decompose it and continue to burn. Red-hot coal will produce the following reaction: $C + CO_2 = 2CO$, which accounts for the production of carbon monoxid in ordinary stoves. A lighted taper put into the gas is instantly extinguished, but ignited magnesium will continue to burn and deposit carbon. The reaction is $Mg_2 + CO_2 = 2MgO + C$.

Lime-water is instantly rendered turbid by the gas, from the formation of insoluble calcium carbonate, thus constituting a test for the gas.

Carbon dioxid has a tendency to accumulate at low levels if produced in large amounts. It is found in undue proportions at the bottom of mine-shafts and in fermenting vats. Cases of suffocation often occur in these places. The usual method of determining whether such places are safe to enter is by lowering a lighted candle; if this continues to burn vigorously, the air is probably safe; if it burns feebly or is extinguished, the air is too rich in the gas.

Carbon dioxid is one of the most important agents in the slow changes which occur in nature. Assisted by the action of frost, it breaks down and renders soluble many kinds of rocks and converts them into soils. The ordinary effervescing soda-water is an artificial solution of the gas under pressure. Fermenting liquids owe their effervescence to the same cause. Under the influence of light, plants decompose it, the carbon being absorbed and the oxygen given off.

Carbonic acid forms a series of salts called the carbonates, most of which are insoluble in pure water. Monads form two salts. Potassium gives us—

$KHCO_3$ . . . . . . Acid potassium carbonate,
K_2CO_3 . . . . . . Potassium carbonate.

Dyads give one salt—

$CaCO_3$ . . . . . . Calcium carbonate.

Carbonic acid is easily recognized by its rendering turbid a solution of calcium hydroxid (lime water) or barium hydroxid (baryta-water). It turns litmus to a wine-red, the blue color being restored on boiling.

Combustion and the Structure of Flame.—Carbon, hydrogen, oxygen, and nitrogen are the especial elements of the tissues of animals and plants from which our fuel and illuminating agents are mostly derived. The process of burning is the absorption of oxygen and the formation of carbonic acid, water, and free nitrogen, and sometimes small amounts of amin and nitric acid. Ordinary flame is gas of some kind in the process of uniting with the oxygen of the air.

Formerly the terms "combustible" and "supporter of combustion" were much used; carbon, phosphorus, and hydrogen being called combustible elements, oxygen and chlorin supporters of combustion. This distinction is now abandoned; the action is a mutual one, and the supporter of combustion may easily be made the combustible.

If we examine common gas or candle flame, we find that it consists of three parts: (*a*) an inner space of a blue color, (*b*) a shell of brightly luminous particles, (*c*) a fringe of feebly luminous particles.

The inner part is the point at which the gas that is burning is produced or escapes. This generally consists of carbon and hydrogen. At its outer edge it meets the air; most of the hydrogen is converted into water, the carbon is set free in a finely divided condition in union with some hydrogen, and this solid is intensely heated by the combustion of the hydrogen. This is the source of the light, and forms the second part. The finely divided matter passes outward and gradually burns, producing the feeble fringe of light, which is the third part. It is obvious that with bodies which are deficient in carbon, or which are burned in a supply of oxygen sufficient to consume the carbon before it can be set free, very little light will be produced; on the other hand, if the quantity of carbon is large, the flame will not be able to heat it above a red heat, and the supply of oxygen may not be sufficient to burn it up; and we then have a lurid, smoky flame.

Alcohol, which contains little carbon, burns without much light; turpentine, which contains much carbon, burns with a red flame and smoke. By making a mixture of the two a good flame may be obtained.

Anything which cools the carbon down below its burning point will cause it to deposit in the solid form; hence the formation of soot or lamp-black when flames come in contact with cold surfaces.

If a chimney is placed over a smoky flame, the increased draft causes a more abundant supply of air, and the carbon is completely burned. This is the reason for the use of chimneys in oil-lamps.

If a flame be suddenly cooled, as by the introduction of a coil of wire or a sheet of wire gauze, the combustion will cease and the mixture of gas and air will escape. This can be easily shown by putting a piece of wire gauze across a gas flame, when it will be found that the flame will stop at the gauze, but a combustible mixture of gas and air will pass through it. Similarly, the gas may be lighted above the gauze and the flame will not run back. If the gauze becomes hot, the flame will pass through. This principle is made use of in Davy's safety-lamp for preventing explosions in mines. It consists of a lamp arranged so that no air or gas can get in except through fine gauze. If an explosive mixture finds its way to the flame, its combustion is limited to the interior of the lamp, at least for a time.

If common coal gas be mixed with air, it will burn with a non-luminous, smokeless flame; and such lamps are now used very largely. In the simplest form, the Bunsen burner, the air is drawn in through openings at the bottom. A great variety of these lamps is now made. Heating by electricity is gradually taking the place of other methods.

When a current of air is driven into a flame its temperature is increased. This is the cause of the efficacy of the mouth blowpipe and of blast-lamps.

When mixtures of gas and air are ignited, combustion may occur through the entire mass at once. This constitutes an explosion. Recent research has shown that violent explosions may occur from the rapid ignition of fine particles of coal, flour, or other combustible material diffused through the air.

Flame Tests.—Many elements give characteristic colors to flames.

Such tests are very delicate, and when applied to pure substances very satisfactory. When several colors are present, one color may conceal the other, and thus the test be incomplete. By passing the light through a prism, the colors are separated, and each may be recognized. The apparatus for this purpose is called a spectroscope. Observations with it show that most elements give out light which is made up of several colors.

Carbon Disulfid, CS_2.—This body is analogous to carbon dioxid. It is produced by passing vapor of sulfur over red-hot charcoal. It is a colorless liquid, which, when quite pure and in large quantity, has a rather pleasant odor, but when impure, and especially when diffused through the air in small quantity, is quite disagreeable. It is very volatile and inflammable, and has high solvent powers, dissolving sulfur, phosphorus, and most oils and fats, and is much used for such purposes. Its vapor will take fire much below a red heat.

Carbon Chlorid.—Carbon forms several compounds with chlorin :—

Marsh gas, CH_4, for instance, yields, by successive substitution action, the following compounds :—

CH_3Cl	Monochlormethane.
CH_2Cl_2	Dichlormethane.
$CHCl_3$	Trichlormethane.
CCl_4	Tetrachlormethane.

The third body, $CHCl_3$, is chloroform; the fourth is carbon tetrachlorid.

Cyanogen, CN.—Cyanogen is a radicle, and in its chemical relations resembles such elements as Cl, Br, and I. It forms compounds called *cyanids*. In all of these it acts as a monad: thus we have hydrogen cyanid, HCN, potassium cyanid, KCN. Dyads require two molecules of cyanogen. Calcium cyanid is CaC_2N_2 or $Ca(CN)_2$. The symbol Cy is often used in formulæ instead of the symbol CN. We may write HCy instead of HCN, KCy instead of KCN.

SILICON.

Silicon, Si, 28, occurs very abundantly as oxid, SiO_2, and as silicates. Silicon exists in three forms, amorphous, graphoidal, and diamond, corresponding to those of carbon. When strongly heated in the air it burns, producing SiO_2.

Silicon is a tetrad, and is related to carbon in many ways, especially in assuming allotropic forms. Compounds have been obtained in which it has replaced carbon.

Silica, Silicic Anhydrid; SiO_2.—This is a widely distributed body, occurring free as common sand, chalcedony, quartz, etc., and in combination forming silicates in great variety, of which clay, granite, feldspar, and sandstones are instances. A very large proportion of the solid substances in the earth's crust is in the form of compounds of silica. Silica exists in the stems of grasses and in the teeth and bones of animals.

In its pure forms silicic anhydrid is a colorless, nearly infusible and insoluble solid, destitute of chemical activity. In nature it often occurs in large six-sided crystals, called quartz or, when ruby-colored, amethyst. Uncrystallized silica also occurs in various conditions—agate, jasper, chalcedony, onyx, etc. In all its forms it is converted into a silicate by fusion with sodium carbonate, and when lime, lead oxid, or other metallic oxids are mixed with the sodium silicates, we get the various forms of glass. When a large excess of sodium carbonate is used, the glass is soluble in water, and is commonly known as soluble glass. The solution is sometimes called *liquid-silex*. It is used as a cement, and in soaps.

Silicic Acid, Orthosilicic Acid, H_4SiO_4.—If sodium silicate be treated with hydrochloric acid, the following reaction occurs :—

$$Na_4SiO_4 + 4HCl = 4NaCl + H_4SiO_4.$$

Solution of silicic acid is tasteless and feebly acid to litmus. By evaporation it forms a gelatinous mass which can be brought to the composition H_2SiO_3, (metasilicic acid), and by further heating gives the insoluble anhydrid.

Silicon combines with the halogens, forming bodies resembling the corresponding carbon compounds.

Silicon and fluorin have a strong affinity, forming silicon fluorid, SiF_4. Silicon combines with positive elements, forming silicids, but many of these are of uncertain composition. Hydrogen silicid, H_4Si, produced by the action of acids upon magnesium silicid, takes fire spontaneously. In its composition it is analogous to marsh gas, H_4C.

TIN.

Tin, Sn, 118, occurs principally as a dioxid, called tin-stone. The element is white, soft, and easily beaten into foil, but is not tough; specific gravity, 7.28. It fuses at 442° F. (228° C.), and resists very well the action of the air and of cold acids. Nitric acid forms a dioxid which immediately takes up water and forms an acid. Tin forms several valuable alloys—pewter, gun-metal, type-metal, bronze, and solder, elsewhere described. Speculum metal, used for metal mirrors, is an alloy of copper and tin; glass mirrors are coated with an amalgam of tin. Tin plate is iron coated with tin by dipping it into a bath of the melted metal. Two series of salts are known—*stannous*, unsaturated, and *stannic*, saturated.

Stannous Oxid, SnO, is a feeble base.

Stannous Chlorid, $SnCl_2$, is formed by dissolving tin in hydrochloric acid. Stannous chlorid is used as a reducing agent. When mixed with mercuric chlorid, mercury is set free and stannic chlorid formed :—

$$HgCl_2 + SnCl_2 = Hg + SnCl_4.$$

Stannous chlorid is used by the dyer as a mordant, under the name of tin crystals.

Stannic Oxid, SnO_2, *Stannic Anhydrid*, is found as a mineral; also produced by burning tin in the air, by oxidizing it with nitric acid, and by adding an alkali to stannic chlorid. It unites with water in various proportions to form acids, and these form salts called stannates and metastannates.

Stannic Chlorid, $SnCl_4$, *Tin Tetrachlorid*, *Libavius' Fuming Liquor.*—This body is largely used by dyers under the name of *nitro-muriate of tin*. It is a colorless fuming liquid, boiling at 239.5° F. (115.3° C.).

Stannic Sulfid, SnS_2, *Mosaic Gold*, is a bronze-colored powder used in printing and coloring.

PLATINUM.

Platinum, Pt, 197.1, occurs native, also alloyed with gold and silver and other elements.

Platinum is hard, white, and very heavy; specific gravity, 2.15; it fuses only at a very high temperature. It resists perfectly the action of the air and of most chemical agents, and for this reason is largely used in chemical operations. It dissolves in hot *aqua regia*, forming platinum tetrachlorid, $PtCl_4$. Platinum forms two series of compounds; its oxids are only feebly basic.

Platinum Tetrachlorid, or *Platinic Chlorid*, $PtCl_4$, is a red or brown deliquescent mass. It forms yellow insoluble precipitates with potassium and ammonium salts, but not with those of sodium, and is of great use in analysis for the separation of potassium from sodium.

The remaining elements are rare and have as yet few applications of moment. Their names, symbols, accepted atomic weights, and valencies will be found in the table of elements. Great scientific interest attaches to some of them, and in a few cases their compounds are used in special tests. Molybdenum in the form of ammonium molybdate, $(NH_4)_2MoO_4$, is used as a test for phosphoric acid. A compound of osmium, OsO_4, is used in microscopy. Osmium itself can be obtained in a crystalline form with a specific gravity of 22.48, being the heaviest substance known. Crookes has shown that the body heretofore known as yttrium includes five or more different elements, or, at least, different molecular groupings; other of the rarer elements show the same condition. Some of the rare elements exist widely diffused in minute amounts.

ORGANIC CHEMISTRY.

NATURE OF ORGANIC BODIES.

Organic Chemistry is primarily the study of the substances which form part of the tissues of plants and animals. These are very numerous, and by various influences, such as action of heat or of oxygen, new bodies may be formed, and these are also included in organic chemistry. At the outset we must carefully distinguish between an ORGANIZED and an ORGANIC body. The former has a definite structure, generally cellular, and is formed under the specific action of vitality. Organic bodies, on the other hand, may or may not possess structure. All organized bodies are organic, but all organic bodies are not organized. For the recognition of the organic nature of any substance the action of heat usually suffices. It causes decomposition, with evolution of smoky, strong-smelling vapors; a residue of carbon remains which can be burned off by heating strongly in the air. The presence of nitrogen is usually indicated by a disagreeable odor like that of burning wool. Amin, NH_3, is often formed and can be detected by appropriate tests. Organized bodies are in general easily recognized by the microscope.

Carbon, hydrogen, nitrogen, and oxygen are by far the most frequent elements which enter into the formation of organic bodies. During the last twenty-five years many artificial bodies have been formed, into which mercury, bismuth, arsenum, chlorin, and iodin have been introduced; these, although analogous to natural organic bodies, are not capable of forming part of healthy tissue. Carbon is present in almost all organic bodies, and for this reason organic chemistry has sometimes been called the "chemistry of the carbon compounds." Hydrogen is also almost always present; oxygen somewhat less frequently; nitrogen still less frequently; while sulfur, phosphorus, and iron are rather exceptional in their occurrence. The following table gives a list of bodies belonging to different classes in organic chemistry, and shows how many changes may be made in the combination of these few elements. The compounds all occur ready formed in nature:—

$C_{10}H_{16}$	Oil of turpentine.
$C_{12}H_{22}O_{11}$	Cane sugar.
$C_{10}H_{14}N_2$	Nicotin (from tobacco).
$C_{14}H_{19}NO_3$	Morphin (from opium).
$C_2H_7NSO_3$	Taurin (from bile).
$C_3H_9PO_6$	Phosphoglyceric acid (from brain).
$C_{32}H_{32}FeN_4O_6$	Hematin (from blood).

Proximate and Ultimate Composition.—The tissues of plants and animals, or the products of their decomposition, are generally mixtures of several independent substances. Butter is a mixture of four or five fats; common rosin contains two or sometimes three distinct bodies; opium and Peruvian bark are still more complicated, and brain and muscle structures are so complicated that as yet complete analyses have not been made of them. The substances which thus exist naturally in a state of mixture are called *proximate principles*, the separation and identification of them is called *proximate analysis*, and such of them as give characteristic qualities to the articles in which they occur are generally called *active* or *essential principles*; atropin, for instance, is the active principle of belladonna, for although many different bodies are contained in the belladonna leaf, atropin is the one upon which its physiological activity mainly depends. The *ultimate principles* of a substance are the elements (carbon, hydrogen, etc.) which it contains.

Ultimate analysis, that is, the determination of the proportions of the elements that may be present, although requiring care in manipulation, is practically the same for all organic compounds.

Transformation of Organic Bodies.—In addition to the bodies found ready-formed in plants and animals, many derivative substances are known. These are produced by a great variety of methods, some of which are of general application.

(*a*) ACTION OF HEAT.—The great majority of organic compounds are changed by heat, some only slightly, others completely. Many are converted into new bodies, which escape in the condition of vapors, and may be subsequently condensed. In this way coal, when heated, gives rise to coal gas, coal tar, pitch, etc., these products being mixtures of many *proximate* principles. Such a process is called destructive distillation.

(*b*) ACTION OF OXYGEN.—At high temperatures most organic bodies burn, producing carbon dioxid and water. At low temperatures the oxygen may enter slowly into combination, or, as frequently happens, may substitute the hydrogen, the substitution taking place in the proportion of one atom of oxygen for every two atoms of hydrogen removed. In both these actions the resulting bodies are generally acids.

(*c*) ACTION OF NITRIC ACID.—This varies with the temperature and degree of concentration of the acid. When very strong and cold acid is used, the action is generally a substitution of the molecule NO_2 for H, giving rise to a series of bodies called *nitro-compounds*. When the acid is weak or hot, the action is usually the direct addition of oxygen, according to methods given in the preceding paragraph.

(*d*) ACTION OF CHLORIN.—Chlorin sometimes enters into direct combination, but usually displaces the hydrogen and takes its place, atom for atom. Bromin and iodin act in the same manner.

The substituting actions of oxygen, nitric acid, chlorin, etc., give rise to a very important series of compounds, which are more completely explained below.

(*e*) ACTION OF DEHYDRATING AGENTS.—These are bodies—sulfuric acid and phosphoric anhydrid, for examples—which have a high affinity for water. They act by abstracting hydrogen and oxygen in the proportion of two atoms of H to one of O.

(*f*) SO-CALLED NATURAL CHANGES.—These are *Fermentation*, *Putrefaction*, and *Decay*.

FERMENTATION is a process by which certain organic bodies, particularly forms of sugar, are converted into new substances simpler in composition. The change is dependent on the development of minute living organisms, and the products differ with the nature of the organism.

The conditions necessary to the action are: (*a*) Proper food, especially the ammonium salts and phosphates. These are generally present in the liquid about to be fermented. (*b*) A temperature from 60° to 100° F. (20° to 40° C.). Very strong solutions of sugar will not ferment.

Many substances, especially those which coagulate albumin, have the power to stop fermentation, and are called antizymotics. Among these are boric acid, zinc chlorid, mercuric chlorid, phenol, alcohol, sulfites, many hydrocarbons, etc.

Some important forms of fermentation are—

1. The Vinous, producing chiefly Alcohol, C_2H_6O, and Carbonic Anhydrid, CO_2.
2. The Acetous, producing chiefly Acetic Acid, $C_2H_4O_2$.
3. " Lactic, " " Lactic Acid, $C_3H_6O_3$.
4. *The Butyric, producing* chiefly Butyric Acid, $C_4H_8O_2$.

Each variety of fermentation is dependent upon and caused by special forms of microörganisms.

PUTREFACTION is a change which bodies containing nitrogen, especially organized bodies, undergo when exposed to air. They are usually converted into simpler products, some of which have characteristic and offensive odors, due in part to the sulfur and phosphorus sometimes present in organized tissues. Putrefaction is caused by the development of various forms of microörganisms. Substances which prevent this development will prevent the putrefaction, and are called *antiseptics*.

DECAY.—This is the decomposition of organic bodies by the slow action of oxygen. It takes place too slowly for any increase of temperature to be noticed, and it is rarely incomplete, that is, some portions of the elements escape action. When wood burns with a flame it leaves nothing but the incombustible mineral matter or ash, but when it decays a brown powder is left, which contains some of the original carbon and hydrogen. Decay requires the access of air, the presence of moisture, and a temperature above the freezing point.

ORGANIC SUBSTITUTION.—This is a process by which one or more atoms of a body are removed and their place occupied by an equivalent number of atoms of some other element. The atoms replace one another strictly according to valency. Numerous substitution compounds are described further on; it will be sufficient here to outline the general principles of their formation.

1. *Substitution by Oxygen.*—Oxygen substitutes hydrogen, one atom replacing two of hydrogen; at least two atoms of oxygen are required, one to combine with the liberated hydrogen and the other to take its place. Thus alcohol, when exposed to oxidation, gives the following reaction:—

$$\underset{\text{Alcohol.}}{C_2H_6O} + O_2 = \underset{\text{Acetic Acid.}}{C_2H_4O_2} + H_2O.$$

The bodies produced by oxygen substitution are usually acids.

2. *Substitution by Chlorin.*—Chlorin usually substitutes hydrogen; one atom of chlorin takes the place of one atom of hydrogen, but the hydrogen thus set free combines with an atom of chlorin; so for the complete reaction two atoms of the latter are needed. Thus:—

$$CH_4 + Cl_2 = CH_3Cl + HCl.$$

If further substitution occurs it will be similar:—

$$CH_3Cl + Cl_2 = CH_2Cl_2 + HCl.$$

These reactions are generally obtained by the direct action of chlorin on the organic body. Proceeding in this way with the above case, we finally reach complete removal of the hydrogen and the formation of CCl_4. This method of substitution is almost the only means we have of forming compounds between carbon and chlorin.

Bromid and iodin follow substantially the same law, but do not act so readily. By the action of phosphoric chlorid, hydroxyl is frequently substituted by chlorin.

3. *Substitution by Sulfur.*—Sulfur substitutes oxygen, atom for atom, but only a comparatively small number of such substitution compounds are as yet known. They are usually of very marked odor. As an example of a sulfur substitution we have C_2H_6S, which corresponds to alcohol, C_2H_6O.

4. *Substitution by NO_2.*—This is a substitution for hydrogen, and is the result of the action of strong nitric acid. Each molecule of NO_2 replaces one atom of H. The bodies thus formed are called nitro-compounds, the prefixes bi-, tri-, etc., being used to indicate the presence of two or more molecules of NO_2. The action of nitric acid on benzene results in the formation of nitrobenzene:—

$$C_6H_6 + HNO_3 + C_6H_5NO_2 + H_2O.$$

5. *Substitution by HSO_3*—Many organic bodies, especially those containing only hydrogen and carbon, when treated with sulfuric acid, form substitution compounds, called sulfonic acids, in which the molecule, HSO_3, takes the place of hydrogen in the organic body. Benzene, for instance, gives—

$$C_6H_6 + H_2SO_4 = \overset{\text{Benzenesulfonic Acid.}}{C_6H_5HSO_3} + H_2O.$$

The C_6H_5 replaces the hydroxyl of the acid, not the hydrogen.

Other Substitutions.—Nitrogen may, under certain circumstances, be substituted for hydrogen. The bodies so formed are called *azo*-compounds.

Silicon may replace carbon, but only a few such instances have been observed.

Organic Synthesis.—Until Wöhler prepared urea by heating ammonium cyanate, it was supposed to be impossible to prepare artificially any one of the constituents of animal or vegetable secretions. Within twenty-five years past great advances have been made in the work of producing organic bodies artificially, either directly from mineral substances, or from other organic bodies. These methods are called *organic synthesis*, and throw much light on the molecular structure of the bodies concerned.

Formates, which occur in natural secretions, may be prepared from potassium formate, which may be made artificially by the action of carbon monoxid on potassium hydroxid :—

$$KHO + CO = KCHO_2.$$

Empirical and Rational Formulæ.—When symbols are written so as to express merely the number of atoms of each element, without attempting to show the arrangement or the relations of them, we have what are called *empirical formulæ*. When, in addition to expressing the composition, we endeavor, by the arrangement of the symbols, to express the manner in which the molecules are formed and the relation it has to other bodies, we have *rational formulæ*. Thus, alcohol may be represented empirically as C_2H_6O, but many of the changes which alcohol undergoes indicate that one of its atoms of hydrogen is closely associated with the oxygen, while the other hydrogen atoms are more closely associated with the carbon. Accordingly the formulæ, C_2H_5HO, is used to indicate this arrangement. A perfect rational formulæ should indicate how the body is formed and all the changes to which it tends, but such formulæ are not yet possible to us. In a large number of organic compounds the rational formulæ are not known.

Percentage Composition.—The results of analysis may be expressed without any reference to symbols, or to the number of atoms of the elements present. We may give simply the number of *parts by weight* of each element contained in *one hundred parts* of the body. Thus the composition of ordinary sugar may be stated as :—

Carbon, ...	42.11
Hydrogen, ...	6.43
Oxygen, ...	51.56
	100.00

These figures represent the *percentage composition*. (See page 34.)

Isomerism, Metamerism, and Polymerism.—Many instances are known of two or more bodies entirely different in origin and character, having the same percentage composition. Acetic acid, lactic acid, and glucose all have the composition :—

Carbon, ...	40
Hydrogen, ...	6.66
Oxygen, ...	53.34
	100.00

Similarly, the bodies known respectively as methyl acetate, ethyl formate, and propionic acid have the same composition.

This relation is known as *isomerism*, and if we compare the formulæ of isomeric bodies they fall naturally into two classes, 1st, those that agree both in number of atoms and molecular weight; 2d, those that differ in number of atoms and molecular weight. The compounds methyl acetate, ethyl formate, and propionic acid, form a series of the first class, while acetic acid, lactic acid, and glucose are examples of the second :—

	Empirical Formulæ.	*Rational Formulæ.*	*Mol. Wt.*
Methyl acetate, ...	$C_3H_6O_2$	$CH_3C_2H_3O_2$	74
Ethyl formate, ...	$C_3H_6O_2$	$C_2H_5\ CHO_2$	74
Propionic acid, ...	$C_3H_6O_2$	C_2H_5COOH	74

It will be seen that the rational formulæ are different, but as far as actual number of atoms is concerned the bodies are identical. Such a relation is said to be one of metameric isomerism or *metamerism*. In the other case referred to we have :—

	Empirical Formulæ.	*Rational Formulæ.*	*Mol. Wt.*
Acetic acid, ...	$C_2H_4O_2$	$HC_2H_3O_2$	60
Lactic acid, ...	$C_3H_6O_3$	$HC_3H_5O_3$	90

Here the only agreement is in percentage composition. Such a relation is called *polymeric isomerism*.

Isomeric Modification.—A special form of isomerism is where two or more bodies are identical in comparison and molecular weight, and so nearly alike in properties and reactions as to indicate that they are forms of the same body, but each is under a slight modification. Thus five modifications of the substance called pentyl alcohol ($C_5H_{12}O$) have been described. Each one of these differs slightly from the others in boiling point, action on light, etc., but they are all entitled to the name pentyl alcohol.

These are more intimate relations than ordinary isomerism, and can best be explained by supposing that certain minor differences exist in the molecule, particularly with reference to the position of the carbon atoms.

Determination of the Formulæ of Organic Bodies.—The percentage composition of a body gives only an imperfect clue to its formula; to obtain this latter we must know something of the molecular weight. Now, as a general rule, it is found that the molecular weight is equal to twice the density of the body in state of vapor compared to hydrogen. The determination of the *vapor density* becomes, therefore, an important operation. The use of these determinations of vapor density is shown by the following example. The composition of alcohol might be represented by the formulæ C_2H_6O, $C_4H_{12}O_2$, or any other multiple, because the *proportion* between the elements would remain the same. The vapor density is, however, found to be 23, and since, by the rule above given, the vapor density is half the molecular weight, such a formula must be chosen as shall give a molecular weight of 46. The one which will give this is:—

$$\begin{aligned} C_2 &= 24 \\ H_6 &= 6 \\ O &= 16 \\ &\overline{46} \end{aligned}$$

C_2H_6O is, therefore, the correct formula for alcohol.

The reason for this is shown by the following calculations:—

The molecule of hydrogen is H_2 and weighs 2
" " " alcohol is C_2H_6O " 46

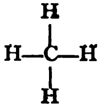
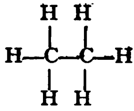
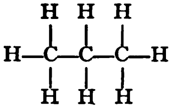
The ratio, therefore, of weight of one molecule (or given volume) of alcohol to a molecule (or given volume) of hydrogen is as 46 to 2 (23 to 1). Since in the determination of vapor density, the comparison is made to hydrogen as unity, the figure obtained by experiment must be doubled to be comparable to the weight of a molecule of hydrogen.

Homologous and Isologous Series.—In many cases when the formulæ of organic bodies, similar in some properties, are arranged in order, they will be found to differ by a regular rate, the carbon increasing or diminishing by one atom and the hydrogen by two. The result is a series of bodies differing by CH_2. Such a series is called a *homologous* series.

In the following examples each vertical column represents five members of a homologous series:—

CH_4	CH_2	C
C_2H_6	C_2H_4	C_2H_2
C_3H_8	C_3H_6	C_3H_4
C_4H_{10}	C_4H_8	C_4H_6
C_5H_{12}	C_5H_{10}	C_5H_8

General Formulæ.—The existence of these homologous series, as above described, renders it possible to express by a single formula the composition of any member of the group. Thus, in the first series, the atoms of hydrogen are always two more than twice the carbon atoms; in its next series the atoms of hydrogen are just twice the carbon; in the third series the hydrogen atoms are two less than twice the carbon atoms. For the first series we could give, then, the general formula $C_n\ H_{2n+2}$; n represents any number of atoms. From this formula we can derive any member of the series; for instance, let it be required to write the formula of the sixth member. As the carbon increases regularly one atom at a time, the sixth member will have six carbons, therefore C_6. Twice six plus two is fourteen; the formula is, therefore, C_6H_{14}. The general formula of the second series above given is $C_n\ H_{2n}$; of the third series $C_n\ H_{2n-2}$.

Carbon Chains.—The valency or combining capacity of each member of a homologous series is the same. It is not difficult to understand how this is, as far as regards the first member of the series, but at first sight it would seem as if each member should have a different valency. Thus, if CH_4 is a saturated molecule, C_2H_6, a homologue with it, would seem to be a dyad; for carbon being a tetrad, two of carbon would have a capacity of eight; six would be saturated by the H_6, leaving two unsatisfied. Experiment, however, shows that C_2H_6 is not a dyad, but a saturated molecule, and so with all bodies homologous with it. The explanation of this fact is upon the supposition that, in forming the molecules, the carbon has in part satisfied itself, so that each atom of carbon added carries into the molecule only two degrees of valency, which the H_2, added at the same time, immediately satisfies. This explanation cannot be made clear without the use of diagrammatic formulæ. Thus the first member of the series would be  $\mathrm{H{-}\overset{\displaystyle H}{\underset{\displaystyle H}{C}}{-}H}$; the second member would have the carbon partly satisfying itself thus:  $\mathrm{H{-}\overset{\displaystyle H}{\underset{\displaystyle H}{C}}{-}\overset{\displaystyle H}{\underset{\displaystyle H}{C}}{-}H}$, the molecule then being saturated. The third would be  $\mathrm{H{-}\overset{\displaystyle H}{\underset{\displaystyle H}{C}}{-}\overset{\displaystyle H}{\underset{\displaystyle H}{C}}{-}\overset{\displaystyle H}{\underset{\displaystyle H}{C}}{-}H}$, and so on with each member. We might give names to the linked carbon atoms—or carbon skeletons, as they have been ingeniously called—calling them di-carbon, tri-carbon, etc.

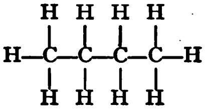
In addition to the arrangement known as open chains, carbon atoms are sometimes arranged in closed chains. For illustration of these forms see *benzene*.

Asymmetric Carbon.—A carbon atom which has no two of its bonds joined to similar atoms or molecules is termed " asymmetric." This condition has important influences on the properties of the compound, especially in its action on polarized light. Any carbon compound which *in solution* has the power to rotate the ray of polarized light will be found to contain at least one atom of asymmetric carbon. Such substances may exist in at least three isomeric forms: one with right-handed rotation, one with left-handed, and one optically inactive. The latter condition may be due either to the existence of equal numbers of atoms of asymmetric carbon of opposite states in the same molecule, or to mixtures of equivalent quantities of the right- and left-handed rotating molecules. Rotation of the polarized ray by solid substances is not necessarily indicative of the presence of asymmetric carbon.

Properties of Bodies in Homologous Series.—The relation of homologous bodies is not a mere accidental relation in formulæ. By comparing different members of the same series we can always see similarities either in origin, general properties, or chemical relation. The series beginning with CH_4 is characterized by general indifference to chemical action. The hydroxids of the series beginning with CH_3 constitute a series of alcohols which possesses specific physiological action. In each series the fusing and boiling points, specific gravity, density of vapor, increase with considerable regularity. The molecular weight, of course, increases, but in the series beginning with CH_2 the percentage composition is the same in all, and they are, therefore, instances of polymeric isomerism. The molecular weight increases regularly, 14, 28, 32, etc., but the percentage composition is always carbon, 85.71; hydrogen, 14.29. By the density of the vapor we can distinguish each one and determine the formula.

Isomeric Modification in Homologous Series.—It has been pointed out, on a previous page, that many organic bodies occur in two or more forms which are not sufficiently distinct to permit us to consider the bodies as different, and yet they are evidently not exactly identical. In such cases the diagrammatic method of showing the linking of the carbon atoms may be utilized to show that the difference of properties in two or more forms of the same body may be due to different positions of the carbon atoms, with respect to each other and to the other elements present. In the lower members of the series, on account of the small number of atoms present, it is generally impossible to make more than one arrangement; but in the higher members several different arrangements are possible, and each arrangement will have certain characteristic indications, either in the chemical or physical properties of the bodies formed. In the series beginning with CH_4 no variation of arrangement can be made in the carbon atoms in the first three members, but in the fourth member, tetrane, C_4H_{10}, we may have no carbon atom united to more than two other carbon atoms, or we may have one carbon to three other carbon atoms:—

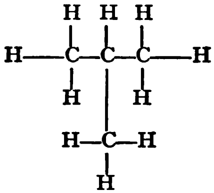
First Form.



$$\begin{array}{ccccccccccc} & & H & & H & & H & & H & & \\ & & | & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & | & & \\ & & H & & H & & H & & H & & \end{array}$$

or $CH_3CH_2CH_2CH_3$

Second Form.



or $CH_3CH(CH_3)CH_3$

In the second compound, the CH_3, which stands rather apart from the remainder of the molecule, may be regarded as a substituting molecule; and the number of isomeric modifications of which any body is susceptible will depend on the number of points at which the substitution can take place. We might formulate the two forms of tetrane very simply thus:—

C_4H_{10}, ordinary tetrane. $C_3H_7(CH_3)$, methyl tritane.

The distinction between such isomeric modifications may often be obtained by determining the substances produced, when the different bodies are subjected to the same decomposing influences.

Classification of Organic Bodies.—No system of classification of organic chemistry is entirely satisfactory. The following will suffice for this work:—

Hydrocarbons (bodies containing C and H).
  Derivatives from the hydrocarbons.
    Fatty series (open carbon chains): Alcohols, ethers, aldehyds, acids, sugars and starches, oils and fats.
    Aromatic series: Benzene and derivatives (closed carbon chains).
Compounds containing nitrogen.
  Cyanogen derivatives, ammonium derivatives, alkaloids, azo-compounds, proteïds.

HYDROCARBONS.

The compounds of carbon and hydrogen are very numerous. Carbon being a tetrad, the highest quantity of hydrogen which can combine with carbon is four atoms. In the compound CH_4 we have the type of the hydrocarbons; all other compounds of this class may be regarded as derived by subtraction or substitution, or both.

If we substitute for all or part of the hydrogen in CH_4 its equivalent of any other substance, we will not disturb the chemical nature; it was a saturated hydrocarbon, and remains so. Hence, CCl_4 will be referable to the same group as CH_4. By successive subtractions of H from CH_4 we may obtain a series of radicles, the valency of which will be equal to the number of hydrogen atoms removed. CH_3 lacks one atom of H; it is a monad *radicle;* CH_2 is a dyad, CH a triad, while C, of course, is a tetrad. From each of the intermediate molecules—hydrocarbon radicles they are called—derivatives may be obtained, comparable in the main to the derivatives which the elements themselves yield. Thus, CH_3 may yield a chlorid, bromid, hydroxid, sulfate, etc., analogous in formulæ to the same compounds formed by the elements of the potassium group. From CH_2 compounds may be obtained analogous in formulæ to those from dyad metals, and so on. In addition, these radicles have substitution power, that is, they may replace the hydrogen of other organic compounds. Each of these radicles and each of their derivatives may constitute the first member of a homologous series. A system of nomenclature by terminations has been adopted to distinguish the different series; the vowels are used in regular order, and the syllable *yl* indicates uneven valency. The number of carbon atoms is indicated, except in the first two members, by syllables formed from the Greek numerals.

It does not necessarily follow that all these bodies have been obtained, but most of them are known, and the others could doubtless be prepared. The members of each vertical column are homologous with each other.

The members of the first series being saturated hydrocarbons, are practically indifferent to chemical agents. Common paraffin is one of them, and the series has, for this reason, been called the *paraffins;* the members of the third series have been called the olefins, from the former name of one of the members of it.

The following table will be sufficient to show the principle of the above classification:—

Series 1	Series 2	Series 3	Series 4	Series 5
Gen. Formula $C_n H_{2n} + 2$. Valency.	Gen. Formula $C_n H_{2n} + 1$. Valency.	Gen. Formula $C_n H_{2n}$. Valency.	Gen. Formula $C_n H_{2n} - 1$. Valency.	Gen. Formula $C_n H_{2n} - 2$. Valency.
O	I	II	III	IV
Methane.	Methyl.	Methene.	Methenyl.	Methine.
CH_4	CH_3	CH_2	CH	C
Ethane.	Ethyl.	Ethene.	Ethenyl.	Ethine.
C_2H_6	C_2H_5	C_2H_4	C_2H_3	C_2H_2
Tritane.	Trityl.	Tritene.	Tritenyl.	Tritine.
C_3H_8	C_3H_7	C_3H_6	C_3H_5	C_3H_4
Tetrane.	Tetryl.	Tetrene.	Tetrenyl.	Tetrine.
C_4H_{10}	C_4H_9	C_4H_8	C_4H_7	C_4H_6
Pentane.	Pentyl.	Pentene.	Pentenyl.	Pentine.
C_5H_{12}	C_5H_{11}	C_5H_{10}	C_5H_9	C_5H_8
Hexane.	Hexyl.	Hexene.	Hexenyl.	Hexine.
C_6H_{14}	C_6H_{13}	C_6H_{12}	C_6H_{11}	C_6H_{10}

PARAFFINS OR METHANE SERIES.

These are saturated molecules not easily affected by chemical agents. Many of them are found in petroleum.

Methane, Marsh Gas, CH_4.—This is a colorless gas existing in common coal gas, being formed during the destructive distillation of coal. It is also produced by decay of vegetable matter, especially under water, and hence is frequently found in marshes, whence its name. By stirring the bottom of a marshy pool, bubbles of methane will escape.

Common Paraffin exists in petroleum and in coal tar. It is a mixture of several of the higher members of the series. It is a white, waxy solid, easily fusible, soluble in ether, little acted on by acids or alkalies. It is used for a protecting coating in chemical apparatus, and as a substitute and sometimes as an adulterant for wax. Cosmolin, vaselin, and similar substances are also in part soft paraffins.

Derivatives of the Paraffins. These bodies are not very easily acted upon by chemical agents, but substitution compounds may be obtained by direct action of chlorin, and even bromin, upon all of them, and nitro-compounds may also be produced directly from some of the higher members.

By successive substitution of the hydrogen in CH_4 we get four bodies which may be given as an illustration of the nomenclature of this kind of compounds:—

Methane,	CH_4
Monochlorinated methane,	CH_3Cl
Di " "	CH_2Cl_2
Tri " "	$CHCl_3$
Carbon tetrachlorid,	CCl_4

The third substitution is the very important body, *Chloroform*, $CHCl_3$. When pure it is a colorless, fragrant liquid, very volatile, specific gravity 1.48, not easy to burn, insoluble in water, and much heavier than that liquid. It boils at 142° F. (61° C.), has high solvent powers, and is a valuable anæsthetic.

Iodoform, CHI_3, is now much used as an antiseptic, especially in surgery. It cannot be obtained by direct substitution, but is easily made by the action of iodin on a mixture of alcohol and potassium hydroxid. It forms bright yellow crystals.

Carbon tetrachlorid, CCl_4, is the final result of the substitution of chlorin for the hydrogen of methane, CH_4. It is a colorless liquid of specific gravity 1.56, freezes at —9° F. (—23° C.), and boils at 172° F. (77° C.). It is a powerful anesthetic.

METHYL SERIES.

This is a series of monad radicles which are usually called the alcohol radicles because their hydroxids are the common alcohols.

Derivatives from the Methyl Series.

Normal oxids, called ETHERS.

$(CH_3)_2O$ . . Methyl ether, analogous to Na_2O, sodium oxid.
$(C_2H_5)_2O$ . . Ethyl ether, " " " "

Compounds with halogens, sometimes called ETHERS.

$(CH_3)Cl$ . . . Methyl chlorid, analogous to NaCl, sodium chlorid.
$(C_5H_{11})Cl$ . . Amyl " " " " "

Compounds derived from acids, called COMPOUND ETHER or ESTERS.

$(CH_3)_2SO_4$ . . Methyl sulfate, analogous to Na_2SO_4, sodium sulfate.
$(C_5H_{11})NO_3$. Amyl nitrate, " $NaNO_3$, sodium nitrate.

The compounds analogous to the acid salts are sometimes called VINIC ACIDS.

$(C_2H_5)HSO_4$. Sulfethylic acid, analogous to $KHSO_4$.
$(C_5H_{11})HSO_4$ Sulfamylic " " "

Hydroxids, called ALCOHOLS.

$(C_2H_5)HO$ . . Ethyl alcohol, analogous to KHO.
$(C_5H_{11})HO$. Amyl " " "

Compounds containing two different radicles, called MIXED ETHERS.

$(CH_3)(C_2H_5)O$ Methyl-ethyl ether.

Chlorids, bromids, hydrids, etc., are known, and many substitution compounds.

Each set of compounds here mentioned constitutes a homologous series.

In general, when alcohols are oxidized by a limited amount of oxygen, two atoms of hydrogen are removed and no oxygen is added. When oxidized in a free supply of oxygen, an atom of oxygen takes the place of the removed hydrogen. The bodies produced in the first case are aldehyds, in the second, acids. In this way we have—

$$\underset{\text{Ethyl Alcohol.}}{(C_2H_5)HO} + O = \underset{\text{Ethyl Aldehyd.}}{C_2H_4O} + H_2O.$$

$$(C_2H_5)HO + O_2 = \underset{\text{Acetic Acid.}}{C_2H_4O_2} + H_2O.$$

Thus each alcohol may be made to yield an aldehyde and an acid, each of these forming one of a homologous series.

The series of acids is very important; many of them exist in fats and oils, hence, they have been called fat-acids. The following table gives a conspectus of some of the most important derivations of the methyl series of hydrocarbons. Of the hydrogen that remains in the acid one atom is replaceable by any positive element or radicle, so that we generally write it apart from the other atoms, as in $HCHO_2$, formic acid. In the table on the next page only a few examples of the compound ethers are given.

Radicle.	Oxids, ethers.	Hydroxids, alcohols.	Aldehydes.	Acids.	EXAMPLES OF COMPOUND ETHERS.		
					Acid sulfates, vinic acids.	Sulfates.	Nitrates.
CH_3	$(CH_3)_2O$	CH_3HO	CH_2O	$HCOOH$	CH_3HSO_4	$(CH_3)_2SO_4$	CH_3NO_3
C_2H_5	$(C_2H_5)_2O$	C_2H_5HO	C_2H_4O	CH_3COOH	$C_2H_5HSO_4$	$(C_2H_5)_2SO_4$	$C_2H_5NO_3$
C_3H_7	$(C_3H_7)_2O$	C_3H_7HO	C_3H_6O	C_2H_5COOH	$C_3H_7HSO_4$	$(C_3H_7)_2SO_4$	$C_3H_7NO_3$
C_4H_9	$(C_4H_9)_2O$	C_4H_9HO	C_4H_8O	C_3H_7COOH	$C_4H_9HSO_4$	$(C_4H_9)_2SO_4$	$C_4H_9NO_3$
C_5H_{11}	$(C_5H_{11})_2O$	$C_5H_{11}HO$	$C_5H_{10}O$	C_4H_9COOH	$C_5H_{11}HSO_5$	$(C_5H_{11})_2SO_4$	$C_5H_{11}NO_3$

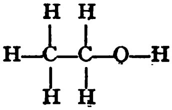
Isomeric modifications are possible in these bodies, except with, methyl, ethyl, and some of their derivatives.

Methods of Forming the Compounds of the Methyl Series.—The starting point is generally the alcohols. The ethers, simple and compound, are produced by the action of acids on the alcohols. The aldehydes are produced by partial oxidation, the acids by complete oxidation; many of the acids exist ready formed in nature.

The alcohols will be described first. They are often called the monatomic alcohols, because they contain a monatomic (*i. e.*, monad) radicle.

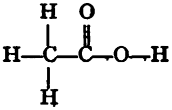
It is shown in the explanation of the nature of acids that the function of an oxygen acid is dependent upon hydroxyl, and that the basicity of such acid is equal to the number of hydroxyl groups present. In consequence of the feebly positive character of the hydrocarbon radicles, the function of any hydroxyl in an organic body will be influenced by the number and position of the negative atoms also present. Accordingly we find many organic hydroxids in which neither strongly acid nor strongly basic properties can be recognized. Thus, common alcohol, C_2H_5HO, acts upon both sodium and sodium hydroxid to form the body NaC_2H_5O, which is called sodium ethylate. In this, however, the alkalinity of the sodium hydroxid is not much diminished. When acetic acid acts upon the same substances, sodium acetate is formed, which is neutral. The difference between the relations of the hydroxyl in alcohol and acetic acid is shown by graphic formulæ—

Alcohol.



$$\begin{array}{ccccccccc} & & \mathrm{H} & & \mathrm{H} & & & & \\ & & | & & | & & & & \\ \mathrm{H} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{O} & - & \mathrm{H} \\ & & | & & | & & & & \\ & & \mathrm{H} & & \mathrm{H} & & & & \end{array}$$

Acetic Acid.



$$\begin{array}{ccccccccc} & & \mathrm{H} & & \mathrm{O} & & & & \\ & & | & & \| & & & & \\ \mathrm{H} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{O} & - & \mathrm{H} \\ & & | & & & & & & \\ & & \mathrm{H} & & & & & & \end{array}$$

Hydroxyl that is united to carbon, which is in turn united to oxygen or other negative body, is known as acid hydroxyl. The molecule, CO, is known as carbonyl, and its combination with hydroxyl, COOH, is called carboxyl. No organic body can be properly called an acid unless it contains hydroxyl associated in this manner with a strongly negative radicle. It is especially carboxyl which is found in organic acids, and the number of carboxyl molecules determines the basicity of the acid. Hydroxyl that is connected directly to unoxidized carbon, that is, is not in the carboxyl or analogous condition, does not confer acid properties and is known as alcoholic hydroxyl.

Methane may be taken as the type of all open chain compounds, these being represented as derived from it by substitution of the hydrogen by various elements or radicles. Each substance so formed may be named in accordance with the substitutions that may be supposed to have occurred.

Thus, by successive substitution of the radicle methyl we get a series of hydrocarbons homologous with methane.

CH_4	Methane.
$CH_3(CH_3)$	Methyl-methane (ethane)
$CH_2(CH_3)_2$	Dimethyl-methane (tritane).
$CH(CH_3)_3$	Trimethyl-methane (tetrane).

By substitution by hydroxyl we get the alcohols—

$CH_3(HO)$	Hydroxymethane.
$CH_2(HO)_2$	Dihydroxymethane.
$CH(HO)_3$	Trihydroxymethane.

By simultaneous substitution by a hydrocarbon radicle and hydroxyl we get alcohols homologous with the above.

$CH_2(CH_3)(HO)$	Hydroxymethyl-methane (hydroxyethane).
$CH(CH_3)_2(HO)$	Hydroxydimethyl-methane,
$CH(CH_3)(HO)_2$	Methyldihydroxymethane.

Simultaneous substitution of oxygen and hydroxyl may develop in connection with the carbon atom, the molecule COOH, carboxyl, and thus produce an acid. Substitution of the remaining hydrogen atom by methyl will produce a homologous acid.

$CH(HO)O$	Oxyhydroxy-methane (formic acid).
$C(CH_3)(HO)O$	Oxyhydroxymethyl-methane (acetic acid),

In the higher members of the series, the substitution may involve either the hydrogen of the methane or that of one of the substituting radicles.

$CH(CH_3)_3$	Trimethyl-methane.
$CH(CH_2CH_3)(CH_3)_2$	Dimethyl-methylmethyl-methane.

Numerous isomeric forms are therefore observed in the higher members of the series, depending on the position of the substituting radicles.

CONSPECTUS OF MONATOMIC ALCOHOLS.

Systematic Name.	Common Name.	Sp. Gr. approx.	Boiling Point.		Source.
			F.	C.	
Methyl	Wood spirit	0.798	151	66.1	Distillation of wood.
Ethyl	Alcohol	0.793	173	78.3	Fermentation.
Trityl	Propyl alcohol	0.820	206	96.6	"
Tetryl	Butyl "	0.803	233	112	"
Pentyl	Amyl " Fusel oil	0.811	270	132	"
Hexyl	Caproic alcohol	0.819	309	154	
Heptyl	Œnanthic "		343	173	Action of KHO on castor oil.
Octyl		0.871	356	180	From parsnip oil.
Nonyl			392	200	
Decyl	Rutic "		414	212	Oil of rue; fuses at 44.5° F. (7° C.).
Dodecyl	Lauric "				Whale oil; fuses at 75° F. (24° C.).
Tetradecyl	Myristic "				
Hexadecyl	Cetyl "				Spermaceti; fuses at 112° F. (90° C.).
Octadecyl	Stearic "				From stearic acid; fuses at 138° F. (59° C.).
	Cerylic "				Chinese wax; fuses at 174° F. (78° C.).
	Melissic "				Beeswax; fuses at 185° F. (85° C.).

Methyl alcohol, $(CH_3)HO$, *wood spirit*, is usually made by distilling wood. The crude material is difficult to purify. Pure methyl alcohol is colorless, and of pleasant odor. It boils at 152° F. (66.5° C.), and its effects on the animal system appear to be less severe and more transient than those of common alcohol. Methylated spirit is a mixture of 90 parts common alcohol with ten parts methyl alcohol.

Ethyl alcohol, $(C_2H_5)HO$, *common alcohol*, *spirit of wine*, is produced in the vinous fermentation of sugar, carbon dioxid being the only other product formed in large amount; it can also be prepared artificially. On the large scale the sprouted grain called malt is generally used. The general nature of the fermentation is explained in connection with the sugars. The fermented *spirit is concentrated by* distillation, but the strongest thus prepared contains about five per cent. of water. To withdraw all the water, it is necessary to distill with quicklime or calcium chlorid, by which *absolute alcohol* is formed. This is inflammable, absorbs water and mixes with it in all proportions.

Proof-spirit contains 50.8 parts by weight of absolute alcohol to 49.2 of water, and has a specific gravity of 0.920. Commercial alcohol is a colorless volatile liquid, of which the properties, effects, and uses are well known. It boils at about 180° F. (81° C.). Alcohol is contained in wine, beer, and spirits; certain essential oils, sugars, or extracts being employed as flavoring agents. Whisky, brandy, and other spirits contain from 40 to 50 per cent. of alcohol; wines, from 17 (Port and Madeira) to 7 or 8 (hock and light clarets) per cent.; porter and strong ale contain from 6 to 8 per cent., lager beer about 4 per cent.; the mild fermented liquors known as mead, root beer, spruce beer, contain from ½ to 1 per cent. The effervescence of fermented liquids is due to the carbon dioxid which is produced with alcohol, thus:—

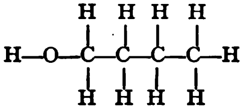
$$\overset{\text{Glucose.}}{C_6H_{12}O_6} \text{ breaks up into } \overset{\text{Alcohol.}}{2C_2H_6O} + 2CO_2.$$

The carbon dioxid is retained by bottling the liquid before the fermentation is over.

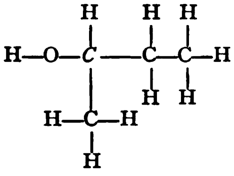
Isomeric Forms of Alcohols.—Methyl and ethyl alcohols present only one form, but a number of isomers of the higher alcohols have been obtained. Comparison of these isomers has led to their division, according to a supposed arrangement of the carbon atoms, into three groups, primary, secondary, and tertiary alcohols.

Primary alcohols contain the group CH_2OH joined to *one* alcohol radicle; secondary alcohols contain the group CHOH joined to *two* radicles, and tertiary alcohol contains the group COH, joined to *three* radicles.

The graphic formulæ show this principle best.

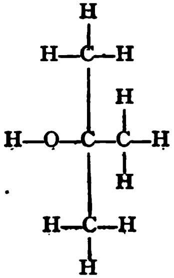


Primary Tetryl Alcohol.
$(C_3H_7)CH_2OH$.



Secondary Tetryl Alcohol.
$(CH_3)(C_2H_5)CHOH$.

In secondary tetryl alcohol an atom of asymmetric carbon exists, indicated (as is now often done) by an italic *C*.



Tertiary Tetryl Alcohol.
$(CH_3)_3COH$.

Pentyl Alcohol, Fusel Oil, $(C_5H_{11})HO$.—The radicle C_5H_{11} has been called amyl, and this alcohol is generally known as amyl alcohol. It is a by-product in fermentation, and is found in raw spirits and new liquors. When pure, it is a colorless, oily liquid, with a peculiar odor, a hot and acrid taste, and decidedly poisonous action.

The alcohols derived from the higher radicles are mostly wax-like.

ETHERS.

The primary alcohols, by the action of bodies which have an affinity for water (sulfuric and phosphoric acids), are converted into oxids, called **ethers.** A *compound ether* is the replacement of the hydrogen of an acid by one or more molecules of a hydrocarbon. The only simple ether of any importance is—

Ethyl oxid, $(C_2H_5)_2O$, common ether, often wrongly called sulfuric ether, usually made by the action of sulfuric acid upon alcohol. Acid ethylsulfate is first formed and then decomposed :—

$$\underset{\text{Alcohol.}}{(C_2H_5)HO} + H_2SO_4 = \underset{\text{Acid Ethylsulfate.}}{(C_2H_5)HSO_4} + H_2O.$$

Another molecule of alcohol is then acted upon, thus :—

$$(C_2H_5)HO + (C_2H_5)HSO_4 = H_2SO_4 + \overset{\text{Ether.}}{(C_2H_5)_2O}.$$

Ether is a colorless, very volatile liquid, of distinct odor, boiling at 98° F. (37° C.). Specific gravity 0.723. Its vapor is inflammable and very heavy. It is a solvent for fats, fixed and volatile oils, resins, and many other proximate principles. Its anesthetic uses are well known.

Compound Ethers.—Many of these have marked odor and are the flavoring materials of flowers and fruits. They can mostly be made artificially, and various mixtures of them are extensively used for imitating flavors.

Ethyl bromid, C_2H_5Br, is an anesthetic.

Ethyl nitrite, $C_2H_5NO_2$, is one of the ingredients of the old remedy known as sweet spirit of nitre.

Pentyl nitrite, $C_5H_{11}NO_2$, often called *amyl nitrite*, is made by the action of nitric acid upon pentyl (amyl) alcohol. It is a yellowish liquid, of well-marked odor, boiling at 205° F. (96° C.).

By the action of potassium or sodium upon alcohols, bodies having caustic properties are obtained. Thus, with sodium and common alcohol, the reaction is :—

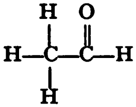
$$C_2H_5HO + Na = C_2H_5NaO + H.$$

C_2H_5NaO is called *sodium ethylate ;* it is a caustic liquid, which has been employed as an escharotic.

SULFUR ALCOHOLS, MERCAPTANS.—The oxygen of organic bodies, as of inorganic bodies, may be replaced by any other element of the oxygen group. Ethyl alcohol, for instance, has a corresponding sulfur compound, C_2H_5HS, called *mercaptan ;* its proper name is ethyl hydrosulfid. Corresponding ethers also are known ; thus $(C_2H_5)_2S$, ethyl sulfid. These sulfur derivatives are mostly strong-smelling and irritating compounds. A few of them exist ready-formed in the secretions of animals and plants. The essential oils of mustard and garlic are sulfur compounds, and are noticed elsewhere.

ALDEHYDES.—These are the results of the removal of two atoms of hydrogen from the alcohols, and stand intermediate between these and the acid. *Ethyl aldehyde*, often called *acetic aldehyde*, or simply *aldehyde*, C_2H_4O, is often present in liquors, especially in raw forms of commercial spirits, and probably gives to such articles some of their injurious qualities. It is a colorless, volatile liquid, lighter than water, and boiling at 70° F. (21° C.), having a powerful affinity for oxygen, and therefore a reducing action. It presents several isomeric modifications, one of which, *paraldehyde*—to which the formula $C_6H_{12}O_3$ has been assigned—has decidedly narcotic properties, and has been used as a substitute for morphine, etc. All the aldehydes of the series form numerous complicated compounds of great chemical interest, but most are as yet of little practical value.

The structural formula of common aldehyde is—



$$\begin{array}{ccccc} & H & & O & \\ & | & & \| & \\ H- & C & - & C & -H \\ & | & & & \\ & H & & & \end{array}$$

It will be noted that no hydroxyl is present, and hence aldehyde has neither acid nor basic properties.

Chloral.—By substituting three atoms of hydrogen in aldehyde, by chlorin, we obtain a colorless liquid heavier than water (specific gravity 1.18), and boiling at 201° F. (94° C.). This is chloral, C_2HCl_3O. It combines with one molecule of water to form a crystalline, pungently-smelling solid, soluble in water, which is now used under the name of chloral hydrate (not hydroxid). It was originally suggested as a hypnotic, on account of the decomposition which it undergoes in alkaline solutions, as shown in the following reaction:—

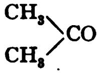
$$\overset{\text{Chloral.}}{C_2HCl_3O} + \overset{\text{Sodium Hydroxid.}}{NaHO} = \overset{\text{Sodium Formate.}}{NaCHO_2} + \overset{\text{Chloroform.}}{CHCl_3}.$$

Formaldehyde, CH_2O, has much practical as well as theoretic interest. It is a powerful antiseptic, preserving thoroughly many perishable articles, milk, etc. It is also a powerful reducing agent. It is considered as the starting point in the formation of the so-called "carbohydrates" of plants. Its formula multiplied by five gives $C_5H_{10}O_5$, pentose, various forms of which are common in plants, and by easy changes may produce the sugars and starches.

KETONES.—By the destructive distillation of calcium acetate, a body called acetone, C_3H_6O, is formed, differing from aldehyde, C_2H_4O, by CH_2.

Acetone is the type of a group known as the *ketones*, which are products of the various reactions, for instance, of destructive distillation.

They contain carbonyl, CO, united to two monad radicles. Common acetone, for instance, is a dimethyl ketone—



FAT-ACIDS.

This term, applicable strictly to only a few of the series, will suffice to distinguish the homologous bodies derived from the alcohols by substitution of *two atoms of hydrogen* by one atom of oxygen. They form an extensive and important class; nearly all of them are natural products. The fixed oils and fats contain some of the higher members of the series. Some have been produced artificially by a reaction, of which the following is a type:—

$$\underset{\text{Ethyl Alcohol.}}{C_2H_6O} + O_2 = \underset{\text{Acetic Acid.}}{C_2H_4O_2} + H_2O.$$

Each of the acids so produced contains one carboxyl group, the hydrogen of which can be replaced by a positive element or radicle, and it is usual to designate this fact by writing the formula with the carboxyl separated from the others, as shown in the following cases. The lower members of the series are freely soluble and miscible with water, strongly acid and irritating, but as the quantity of carbon and hydrogen increases, the compounds become more and more oily, and the higher members are distinctly fatty, feebly acid, insoluble in water, but soluble in alcohol and ether.

Formic Acid, $HCOOH$, originally prepared from the ant, can be made by a number of methods. It is a powerful reducing agent, blisters the skin, and has nearly the same boiling and freezing point as water.

Acetic Acid, CH_3COOH.—This occurs in small quantities in animal and plant juices. In the dilute form it constitutes vinegar, which contains from 3 to 6 per cent. of the acid, and is usually made by oxidizing dilute alcohol in the presence of a ferment. Acetic acid is also produced in the distillation of wood, being in this case generally contaminated with tar, and called pyroligneous acid. When pure, it is a colorless, corrosive liquid, solidifying at 62.6° F. (17° C.), and boiling at 246° F. (119° C.). This is glacial acetic acid. The dilute forms are less active, and in vinegar its effects are quite mild.

ACETATES.—The most important of these are:—

Sodium acetate, $NaC_2H_3O_2$, which forms deliquescent crystals, containing $3H_2O$.

Ammonium acetate, $(NH_4)C_2H_3O_2$, is used in medicine in the form of a solution in water, called spirit of Mindererus.

Lead acetate, $Pb(C_2H_3O_2)_2$, *sugar of lead*, made by dissolving lead monoxid in acetic acid, forms white crystals, soluble in water. By boiling this solution with lead monoxid, a considerable amount of the latter is dissolved, and the *sub-acetate*, more correctly oxy-acetate, is formed, called Goulard's extract, and when much diluted, lead water.

Copper acetate, $Cu(C_2H_3O_2)_2$, is not important; but an irregular and variable compound of it with copper hydroxid, known as *verdigris*, is made by exposing alternate layers of sheet copper and refuse grape skins to the air.

HOMOLOGOUS SERIES OF FAT-ACIDS.

Common Name.	Empirical Formula.	Melting Point. F.	Boiling Point. F.	Properties.	Natural Source.
Formic, ...	CH_2O_2	34	212	Colorless volatile liquid.	In red ants and some other insects and in some stinging plants.
Acetic, ...	$C_2H_4O_2$	62	246	Colorless pungent liquid.	Oxidation of alcohol and sugar.
Propionic, ...	$C_3H_6O_2$	62	256	Crystalline solid.	
Butyric, ...	$C_4H_8O_2$	− 4	322	Colorless liquid of disagreeable odor.	Butter and other animal secretions.
Valeric, ...	$C_5H_{10}O_2$		347	Colorless liquid of disagreeable odor.	Valerian root.
Caproic, ...	$C_6H_{12}O_2$	41	388	Colorless oily body.	Butter and cocoanut oil.
Enanthylic, . . .	$C_7C_{14}O_2$		414	Slightly soluble in water; has an agreeable odor.	Oxidation of castor oil.
Caprylic, ...	$C_8H_{16}O_2$	57	456		Butter, cocoanut and castor oils.
Pelargonic, ...	$C_9H_{18}O_2$	64	500	Crystalline solid.	Geranium leaves.
Capric, ...	$C_{10}H_{20}O_2$	86	505	Crystalline mass having the odor of sweat.	Butter and cocoanut oil.
Lauric, ...	$C_{12}H_{24}O_2$	110		Silky crystals.	In cocoanut oil.
Myristic, ...	$C_{14}H_{28}O_2$	129		Crystalline scales.	In nutmeg and cocoanut oil.
Palmitic, ...	$C_{16}H_{32}O_2$	143		Fat-like solid.	Most natural fats.
Margaric, ...	$C_{17}H_{34}O_2$	140		" "	Resembles palmitic.
Stearic, ...	$C_{18}H_{36}O_2$	156		" "	Most natural fats.
Arachidic, ...	$C_{20}H_{40}O_2$	157		White, crystalline, fatty solid.	Peanut oil.
Behenic, ...	$C_{22}H_{44}O_2$	168		" " " "	Oil of ben.
Hyenic, ...	$C_{25}H_{50}O_2$	171		Resembles Cerotic.	
Cerotic, ...	$C_{27}H_{54}O_2$	172		Crystallizes in small grains.	Free in beeswax.
Melissic, ...	$C_{30}H_{60}O_2$	190			Derived from beeswax.

ethyl alcohol is formed and then converted into acetic acid which acts on the copper.

Ferric acetate, $Fe_2(C_2H_3O_2)_6$, is used in medicine.

Ferrous acetate, $Fe(C_2H_3O_2)_2$.—An impure form obtained by dissolving iron in crude acetic acid; is used in dyeing.

Aluminum acetate, $Al_2(C_2H_3O_2)_6$, is used in dyeing and calico printing.

Butyric (Tetrylic) Acid, C_3H_7COOH.—This may be obtained from butter-fat, and from some fruit flavors, and also by fermentation of sugar with cheese and chalk. It is a colorless liquid having the disagreeable odor of rancid butter.

Valeric (Pentylic) Acid, C_4H_9COOH, is found in valerian root and in other plants. Four isomeric modifications are possible, of which three are known. They have different specific gravities and boiling points. The ordinary form is a colorless liquid of a disagreeable odor. Several valerates, often called valerianates, are used in medicine; among these are those of zinc and ammonium.

Stearic Acid can be obtained from most of the solid animal fats, and from some vegetable fats. It is a white, crystalline body which can be distilled. It is insoluble in water. Among other uses for it is the manufacture of candles. The white candles called stearin are generally made of stearic acid.

Salts of the Higher Fat-Acids.—By substituting the single atom of replaceable hydrogen of the fat-acids we obtain a series of bodies all of which might be called "soaps," but it is only with the higher members of the series that the peculiar physical and chemical characters of the soaps are seen. The derivatives of the lower members are generally soluble in water, but in the higher members most of the compounds are insoluble, except those formed by potassium, sodium, and ammonium. With lead, calcium, and zinc, for instance, we get insoluble soaps.

ETHERS OF THE FAT-ACIDS.

The monad alcohol radicles give with these acids compounds which are more or less volatile and odorous. They are known as compound *ethers* or *esters*. The general method of preparation is to heat a mixture of the sodium salt of the proper acid with the alcohol containing the proper radicle and sulfuric acid. Thus, to produce ethyl acetate we would heat sodium acetate, ethyl alcohol, and sulfuric acid :—

$$C_2H_5HO + NaC_2H_3O_2 + H_2SO_4 = C_2H_5C_2H_3O_2 + NaHSO_4 + H_2O.$$

By using pentyl alcohol and sodium valerate, pentyl (amyl) valerate is formed, and so on. Amyl acetate constitutes banana essence; amyl valerate is apple essence, amyl butyrate has the odor of pine-apples. By various mixtures of these and other ethers almost any flavor may be imitated.

SUBSTITUTION DERIVATIVES.

The hydrogen that is part of the radicle of these acids may be substituted by members of the chlorin group, particularly by chlorin itself. From acetic we get three compounds, all of which closely resemble the original acid:—

$HC_2H_3O_2$	Acetic acid.
$HC_2H_2ClO_2$	Monochloracetic acid.
$HC_2HCl_2O_2$	Di " "
$HCCl_3O_2$	Tri " "

These compounds are usually obtained by the direct action of chlorin. By indirect means, the use of phosphoric chlorid, for instance, the chlorin may be made to replace the hydroxyl of the acid; in this manner the acid properties are removed, and chlorids formed with the acid radicles. Acetic acid gives the following:—

$$\overset{\text{Acetic Acid.}}{CH_3COOH} + PCl_5 = \overset{\text{Acetyl Chlorid.}}{CH_3COCl} + POCl_3 + HCl.$$

Similar compounds may be obtained from bromin.

OLEFINS, OR METHENE SERIES.

The second member of this series, ethene, C_2H_4, was called, when first discovered, olefiant (oil-making) gas, because it combines with chlorin to form an oily liquid; for this reason the series has been called the *olefins*. They are dyad radicles, which form alcohols, ethers, and other derivatives; but these derivatives are greater in number than from monad radicles, on account of the higher valency. Two series of acids are yielded by the action of oxygen on the alcohol, instead of one, as in the case of the monad radicles.

Name.	Melting Point.		Boiling Point.	
	F.	C.	F.	C.
Ethene	. .	. .	Gaseous.	
Tritene	. .	. .	0.4	—18
Tetrene	. .	. .	33.8	1
Pentene	. .	. .	95	35
Hexene	. .	. .	149	65
Heptene	. .	. .	205	96
Octene	. .	. .	248	120
Nonene	. .	. .	284	140
Decene	. .	. .	320	160
Pentedecene	. .	. .	482	250
Hexdecene	. .	. .	527	275
$C_{20}H_{40}$	. .	. .	752	400
$C_{27}H_{54}$	135	57	. .	. .
$C_{30}H_{60}$	144	62	. .	. .

The ratio between the weights of the hydrogen and carbon is the same in each member of the series, so that the percentage composition is the same throughout the series, but the molecular weight increases. The members of the series are polymeric isomers.

DERIVATIVES.—The olefins combine directly with the chlorin group to form dichlorids. Ethene dichlorid, $C_2H_4Cl_2$, was originally called *Dutch liquid*, because discovered by an association of Dutch chemists.

By indirect means oxids and ethers may be formed and also hydroxids, containing, of course, two molecules of HO and known as DIATOMIC ALCOHOLS or GLYCOLS. Each of these alcohols yields by oxidation *two* acids, one derived by the replacement of two atoms of hydrogen by one atom of oxygen, and the other by the replacement of four atoms of hydrogen by two atoms of oxygen. The first is the *lactic acid* series; the second, the *oxalic acid* series. For instance, ethene glycol gives the following:—

$$C_2H_4(HO)_2 + O_2 = H_2O + \overset{\text{Glycolic Acid.}}{HOCH_2COOH}.$$

$$C_2H_4(HO)_2 + O_4 = H_2O + \overset{\text{Oxalic Acid.}}{COOHCOOH}.$$

Oxalic acid is, therefore, dicarboxyl. Methene glycol, $CH_2(HO)_2$, has not been obtained. By oxidation it could form but one acid, carbonic, $(HO)_2CO$, which may be regarded as the first member of the first series.

Radicle.	Oxids, Ethers.	Hydroxids, Alcohols.	Acids by first oxidation.	Acids by second oxidation.
C_2H_4	C_2H_4O	$C_2H_4(HO)_2$	Glycolic acid. $C_2H_4O_3$	Oxalic acid. $C_2H_2O_4$
C_3H_6	C_3H_6O	$C_3H_6(HO)_2$	Lactic acid. $C_3H_6O_3$	Malonic acid. $C_3H_4O_4$
C_4H_8	C_4H_8O	$C_4H_8(HO)_2$	Oxybutyric acid. $C_4H_8O_3$	Succinic acid. $C_4H_6O_4$

The acids of the first, containing one molecule of alcoholic hydroxyl and one molecule of carboxyl, are called hydroxy-acids.

Ethene oxid, C_2H_4O, is isomeric with common aldehyde, but is not identical with it.

Acid Derivatives of the Glycols.—These are the most important. The first (lactic) series is monobasic, that is, has a single atom of replaceable hydrogen; the second (oxalic series) is dibasic, that is, has two atoms of replaceable hydrogen.

LACTIC SERIES.

Name.	Formula.	Melting Pt.		Boiling Pt.		Source.
		F.	C.	F.	C.	
Glycolic . .	$C_2H_4O_3$	176	80	212	100	By oxidation of ethene glycol.
Lactic . . .	$C_3H_6O_3$	. .	. .	. .	. .	By fermentation of milk sugar.
Oxybutyric .	$C_4H_8O_3$	. .	. .	. .	. .	By oxidation of butyric acid.
Oxyvaleric .	$C_5H_{10}O_3$	176	80	. .	. .	By oxidation of valeric acid.
Leucic . . .	$C_6H_{12}O_3$	164	73	212	100	Occurs in animal products; also formed by decomposition of horn, glue, etc.

Lactic Acid, $(HO)C_2H_4(COOH)$.—This important acid exists in at least three isomeric modifications.

(*a*) *Ordinary lactic acid* exists in gastric juice, and is a product of fermentation of milk sugar. It is a colorless, syrupy, very sour liquid, which has not yet been obtained in the solid state. It can be obtained in quantity by allowing *a mixture of* cane sugar, cheese, sour milk, and chalk, or zinc oxid, to ferment for several days. The resulting calcium or zinc lactate can be purified and the lactic acid obtained from it.

(*b*) Paralactic acid and (*c*) ethene-lactic acid, two isomers of ordinary lactic acid, occur together in muscular tissue, and were formerly included under the title sarcolactic acid.

Several lactates are used in medicine. Lactic acid is one of the products of the growth of fungi around the teeth, and is an important factor in dental caries.

OXALIC SERIES.

Name.	Formula.	Melting Pt.		Source.
		F.	C.	
Oxalic . . .	$H_2C_2O_4$	. .	. .	Oxidation of sugar, starch, and cellulose.
Malonic . .	$C_3H_4O_4$	284	140	Oxidation of malic acid.
Succinic . .	$C_4H_6O_4$	356	180	Distillation of amber; oxidation of fat-acids.
Pyrotartaric .	$C_5H_8O_4$	234	112	Action of heat on tartaric acid.
Adipic . . .	$C_6H_{10}O_4$	284	140	" " nitric on sebacic acid.
Pimelic . .	$C_7H_{12}O_4$	273	134	" " potassium hydroxid on camphoric acid.
Suberic . .	$C_8H_{14}O_4$	257	125	Action of nitric acid on cork or castor oil.
Anchoic . .	$C_9H_{16}O_4$	241	116	Action of nitric acid on coconut oil.
Sebacic . .	$C_{10}H_{18}O_4$	261	127	Distillation of oleic acid.
Rocellic . .	$C_{17}H_{32}O_4$	270	132	Exists in some lichens.

Oxalic Acid $(COOH)_2$.—The free acid and its salts, especially acid potassium oxalate, occur in many plants, generally in the form of crystals—called raphides—deposited in special cells in the leaves or stems.

Oxalic acid forms colorless crystals, having the composition $H_2C_2O_4,2H_2O$. It is freely soluble in water, and is one of the most rapidly fatal poisons known. Death has occurred in ten minutes after administration. The antidote is lime. Preparations of the acid are sold under the misleading names of salt of sorrel, and salt of lemon, and used for taking out ink stains.

Ammonium oxalate, $(NH_4)_2C_2O_4$, forms white crystals, soluble in water, and much used as a test for calcium compounds.

Calcium oxalate, CaC_2O_4, is thrown down as a white precipitate by adding an oxalate to calcium chlorid. It is sometimes found in the urine in microscopic octahedral or dumb-bell crystals. In larger masses it constitutes mulberry calculus.

Succinic Acid, $C_2H_4(COOH)_2$.—This occurs in amber and other resins; also in small quantities in some animal secretions. It forms colorless crystals, soluble in water.

Somewhat related to the series just described, although not necessarily referable to the same radicles, are two important vegetable acids, malic and tartaric. The relation is especially with succinic acid, from which they differ only in amount of oxygen:—

	Empirical Formulæ.
Succinic	$C_4H_6O_4$.
Malic	$C_4H_6O_5$.
Tartaric	$C_4H_6O_6$.

Malic Acid, $H_2C_4H_4O_5$, occurs in many sour fruits, as apples, pears, and mountain ash berries. It may be made artificially from succinic acid. It is crystalline, sour, soluble in water and alcohol. The malates are mostly soluble in water. Sweet cherries contain potassium malate.

Tartaric Acid, $(HO)_2C_2H_2(COOH)_2$ is found in many plants, but especially in grapes, where it exists as acid potassium tartrate, $KHC_4H_4O_6$. This is somewhat soluble in water, but scarcely soluble in dilute alcohol; and hence, in the manufacture of wine, as the fermentation advances, the quantity of alcohol increases, and tartrate deposits as a red mass called *argols* or *tartar*; when this is dissolved in water and purified by crystallization it constitutes *cream of tartar*. Tartaric acid presents several isomeric modifications, all of which contain asymmetric carbon. The ordinary acid is a crystalline body, soluble in water, forming a very sour solution which develops a fungous growth and decomposes.

Acid potassium tartrate, cream of tartar, is a white crystalline body, very sour, and not very soluble in cold water. It is used in effervescing powders.

Potassium tartrate, $K_2C_4H_4O_6$, is called soluble tartar.

Sodio-potassium tartrate, $NaKC_4H_4O_6$, is known as *Rochelle salt*.

Tartar emetic is made by boiling acid potassium tartrate with antimonous oxid, by which an atom of hydrogen is replaced by the molecule SbO. The formula for tartar emetic is $K(SbO)C_4H_4O_6$, potassium antimoxyl tartrate.

Citric acid, $(HO)C_3H_4(COOH)_3$, is the acid of lemons and oranges, and is also found in some other fruits. It is a crystalline body, very sour, and easily soluble in water. It is used in the preparation of effervescing mixtures, but *some of the so-called* effervescing citrates contain tartaric instead of citric acid.

METHENYL SERIES.

These are triad radicles. The first member, CH, methenyl, may be regarded as existing in chloroform. The most important member of the group is tritenyl, C_3H_5, also called propenyl. Its hydroxid, $C_3H_5(HO)_3$, is glycerol. Many of the common oils and fats are compound ethers of tritenyl, and when treated with alkalies, such as sodium hydroxid, are broken up; a new salt and tritenyl hydroxid is formed. On tritenyl stearate (one of the ingredients of common animal fat) sodium hydroxid—common lye—would act thus:—

$$\overset{\text{Tritenyl Stearate.}}{(C_3H_5)(C_{18}H_{35}O_2)_3} + 3NaHO = \overset{\text{Sodium Stearate.}}{3NaC_{18}H_{35}O_2} + \overset{\text{Glycerol.}}{C_3H_5(HO)_3}.$$

Sodium stearate is a *soap*, and the process is saponification. The formation of glycerol can also be brought about by the use of superheated steam. This method is now generally used, since it gives the fat-acids in the free condition, thus:—

$$C_3H_5(C_{18}H_{35}O_2)_3 + 3H_2O = C_3H_5(HO)_3 + 3HC_{18}H_{35}O_2.$$

Glycerol (Glycerin), $C_3H_5(HO)_3$.—Pure glycerol is a colorless, viscid liquid, miscible in all proportions with water and alcohol. Specific gravity 1.27. It has a marked sweet taste, absorbs water from the air, but does not otherwise change. Under certain conditions it can be distilled without decomposition. It solidifies at about —40° F. and C. It dissolves a great many substances, standing, in fact, next to water in its range of solvent powers. It is produced in small quantity during the fermentation of sugar, hence is often found in ordinary liquors. It is sometimes called the "sweet principle of fats," but it does not exist in fats, and possesses no chemical analogy to them. It is an alcohol, and is probably somewhat analogous to the sugars. Its use, therefore, as an application to the skin as a substitute for the emollient oils has no chemical justification.

When treated with strong nitric acid, it forms tritenyl nitrate, $C_3H_5(NO_3)_2$, known as nitro-glycerol. This is powerfully explosive, especially by percussion. It is now extensively used as a blasting agent, being generally mixed with some inert powder, constituting dynamite.

FATS AND FIXED OILS.

The fats and fixed oils are almost all compound ethers of tritenyl. Most of the natural forms are mixtures of two or more distinct ethers. Names are applied to them according to the acid from which the ether is derived. Thus, tritenyl stearate, $C_3H_5(C_{18}H_{35}O_2)_3$, is called *stearin*; tritenyl butyrate, C_3H_5

$(C_4H_7O_2)_3$, is called *butyrin*, and so on. These substances, therefore, constitute the *proximate principles*. The fixed oils are fats with a low melting point, and may be divided into two classes; drying oils, which absorb oxygen from the air, and become hard and resinous, such as linseed and poppy oil; non-drying oils, which remain fluid, as castor and sperm oils. Many fats and oils undergo partial decomposition in the air, producing acids; this is called rancidity. When an alkali is added to a fat, decomposition takes place, a salt is formed, constituting a soap, and glycerol is produced. Soaps produced by potassium hydroxid are usually soft; those from sodium hydroxid, hard; those made from other oxids are mostly insoluble in water. This latter fact explains the curdling action of limestone waters. The calcium and magnesium compounds in these waters produce insoluble soaps. When soluble soaps are treated with cold water they decompose into acid salt, which precipitates and makes the soapsuds, and a basic salt, which dissolves and gives the cleansing action.

The fat-acids may be obtained by adding a strong acid to ordinary soaps.

The fats are all insoluble in water, but are soluble in ether, chloroform, benzene, and carbon disulfid. They are decomposed by heat, and consequently cannot, under ordinary circumstances, be distilled.

The proximate constituents of the common fats are given under condensed names, the significance of which is as follows:—

Stearin is tritenyl stearate.
Palmitin is " palmitate.
Margarin is " margarate.
Butyrin is " butyrate
Olein is " oleate.

Human fat contains olein and palmitin.

Oleic acid is not a member of the same series with the other acids. It belongs to a series beginning with acrylic acid, $C_3H_4O_2$, and is elsewhere described.

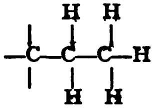
The following table of properties of the important fats and oils is condensed from Allen's tables:—

Name.	Sp. Gr. at 15° C.	Melting point, Centigrade.	Distinctive Proximate Constituents.
Olive	0.916	+ 4 to — 6	Olein, palmitin, and some stearin.
Almond	0.918	— 10 to — 20	Olein and palmitin.
Peanut	0.918	— 5	Arachidin and hypogœin.
Rape	0.915	— 6 to — 10	Brassin.
Cottonseed . .	0.926	1 to 4	Olein and stearin.
Sesame	0.922	+ 5 to 6	Olein and myristin.
Linseed	0.935	— 20 to — 27	Linolein and myristin.
Castor	0.960	— 18	Ricinolein and palmitin.
Croton	0.950	. .	Tiglin, crotonin, and valerin.
Palm	0.945	25 to 36	Olein and palmitin.
Cacao	0.995	30 to 34	Olein and stearin.
Coconut . . .	0.874*	20 to 28	Laurin.
Neatsfoot . . .	0.915	Below °	
Lard oil	0.915	— 4 to + 10	Olein.
Tallow	0.862*	36 to 49	Olein, palmitin, and stearin.
Lard	0.861	28 to 45	" " " "
Wool fat . . .	0.888		
Butter	0.870	29 to 35	" " " butyrin.
Whale	0.925	. .	Valerin.
Cod-liver . . .	0.927	. .	Olein and myristin.
Sperm	0.880	. .	These contain fats derived from other radicles than tritenyl, and hence do not yield glycerin when saponified.
Spermaceti . .	0.810*	43 to 49	
Beeswax . . .	0.825*	62 to 64	

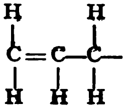
* Taken at 99° Centigrade.

ALLYL AND DERIVATIVES.—Allyl, C_3H_5, is isomeric with tritenyl, but unlike it is a monad, the carbon atoms neutralizing the valency of each other more completely than in the case of tritenyl. By graphic formulæ the difference may be thus represented:—

Tritenyl, Triad.



Allyl, Monad.



Allyl alcohol is C_3H_5HO. Allyl is chiefly interesting on account of the occurrence in nature of two of its compounds, allyl sulfid, $(C_3H_5)_2S$, which is the essential *oil of garlic*, and allyl thiocyanate, C_3H_5CNS, *volatile oil of* *mustard.* Allyl aldehyde, C_3H_4O, is one of the products of the decomposition of fats by heat, and is the main cause of the irritating vapors which are caused by such decomposition. The oxidation of allyl aldehyde gives acrylic acid, which is the first member of a series of acids derived from some of the fats. The most important of this list is oleic acid.

Oleic acid, $C_{17}H_{33}(COOH)$, exists in most natural fats and non-drying oils as olein—tritenyl oleate. It is solid at 57° F. (14° C.). Above this temperature it is a clear liquid, lighter than water, and insoluble in it, but soluble in alcohol and ether. Crude oleic acid, made by the decomposition of fats by steam, as mentioned elsewhere, is used in soap making, under the name of red oil. Various oleates, *e. g.*, copper, bismuth, zinc and mercury oleates, are now used as substitutes for ointments. They are usually prepared by the reaction of sodium oleate with some suitable compound. Thus copper oleate is formed by mixing copper sulfate with sodium oleate.

TURPENES.

The molecule $C_{10}H_{16}$ represents the composition of a large number of *volatile* or *essential oils*. These often exist in plants, in association with oxidized products of higher boiling point, called resins, constituting an oleoresin. When this is heated the oil distills and the resin is left. Gum is also sometimes present, thus making a *gum-resin*. A *balsam* is a similar mixture containing benzoic or cinnamic acid. Of the volatile oils having this composition, the most important is—

Oil of Turpentine, obtained from turpentine, which is an exudation from pine trees, consisting of resin and volatile oil. On being distilled the volatile oil is collected in a receiver; the resin remaining constitutes common rosin. Oil, or spirit of turpentine, is a thin, colorless liquid. It is lighter than water, boils at 320° F. (160° C.), and is a valuable solvent. It is partially oxidized in the air.

By passing air through warm oil of turpentine a partially oxidized product is formed, which, when shaken with water, will produce some hydrogen dioxid. The oxidized oil is now sold as a disinfectant, under the name of "Sanitas."

Some of the oils which have the same composition are lemon, bergamot, coriander, hop, juniper, and valerian. They are called *essential oils*, are mostly lighter than water, and freely soluble in ether and alcohol. Though agreeing in composition, they differ in specific gravity, boiling point, and in other properties. Many of them, by exposure to air, undergo oxidation and other changes, in time becoming resinous and acquiring an odor something like oil of turpentine.

Many of the essential oils are mixtures of several substances.

CAMPHORS AND RESINS.—Plants furnish us with a number of oxidized turpenes, among which are the *camphors* and *resins*.

Common camphor, $C_{10}H_{16}O$, obtained from the camphor laurel, is a white, crystalline solid, volatile at ordinary temperatures. It is slightly soluble in water, and freely in alcohol and ether. By the action of hydrochloric acid on oil of turpentine a body having the odor of camphor is formed.

Another form of camphor, called Borneo camphor, has the formula, $C_{10}H_{18}O_2$.

Resins include a large group, of which many are true acids, and form salts, constituting resin soaps.

Common rosin is the residue from the preparation of oil of turpentine. It is a mixture of two acids. As a class the resins are easily fusible, insoluble in water but soluble in alcohol.

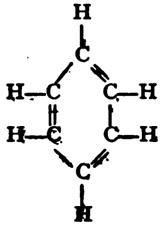
Amber and copal are fossil resins—that is, are found in fossil vegetable matter. Lac, mastic, sandarach, and dragon blood are used in varnishes.

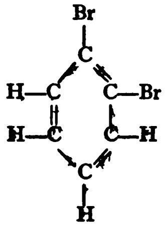
Caoutchouc and *gutta percha* are turpenes found in the juices of some plants. They are insoluble in water, but in the plant are usually in suspension, very finely divided so as to make a milky liquid, called an emulsion. Caoutchouc is elastic; gutta percha is not. Both are capable of combining with sulfur when heated to about 300° F. (150° C.). The process is called vulcanizing, and the hardness of the product can be regulated by the amount of sulfur and the temperature used, so that valuable materials are prepared in this way. Caoutchouc dissolves in benzene and petroleum spirit. Gutta percha is soluble in chloroform.

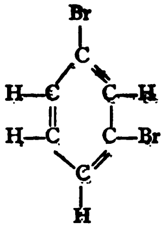
BENZENES.

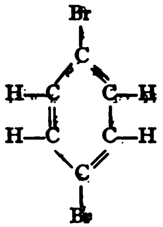
Benzene, C_6H_6, is the first member of a series which possesses great interest on account of the number of isomeric compounds which have been obtained. The hydrogen is susceptible of replacement by various elements and radicles; and we may get in this way not only a number of compounds, but different atoms of H replaced by the same substance give different bodies. Thus, dibromobenzene, $C_6H_4Br_2$ exists in three different forms, called respectively ortho, meta, and para-dibromobenzene.

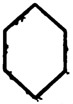
These facts are explained by graphic formulæ, in which the substituting bodies are shown in different positions in the different isomers.

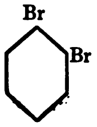

Benzene.

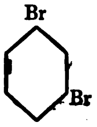

Ortho-dibromobenzene.

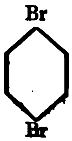

Meta-dibromobenzene.


Para-dibromobenzene.

In such formula it is usual, in order to avoid confusion, to write the benzene molecule  omitting the hydrogen. The three dibromobenzenes given above would be expressed thus:—



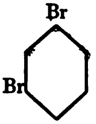


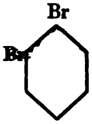


The terms *ortho*, *meta*, and *para* may be abbreviated to *o*, *m*, and *p*.

The number and complexity of the isomers generally increases as the number of the substituting bodies increases, and especially when different *radicles are concerned.*

It might seem that in addition to the three substitution compounds with bromin above given, the following forms should also exist:—

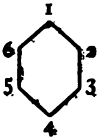




The first of these positions is, however, symmetrical with that representing the meta-form, and the second position is symmetrical with that representing the ortho-form, and neither, therefore, expresses a new condition of isomerism. As a matter of fact only three dibromobenzenes are known.

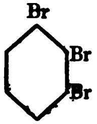
The supposed arrangement of the carbon atoms in benzene, called the benzene ring, constitutes a simple example of the "closed" carbon chain. The molecular union is very strong, and enables the carbon to resist powerful chemical agents, such as nitric and chromic acids, much better than is the case with the open chain compounds.

The angles of the hexagon are distinguished by numbers in the order of those on the face of a clock, thus:—

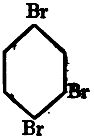


The different substitution compounds are often indicated by these numbers. Thus, ortho compounds are called 1–2 compounds, meta, 1–3, and para, 1–4.

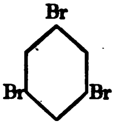
When three atoms of hydrogen are substituted by the same monad, three forms are produced as follows:—



Consecutive (1, 2, 3)
Tribromobenzene.



Unsymmetrical (1, 3, 4)
Tribromobenzene.

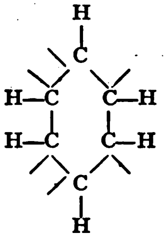


Symmetrical (1, 3, 5)
Tribromobenzene.

Comparison with other positions of the three atoms of bromin will show that the above are the only distinct forms; investigation shows that three, and only three, tribromobenzenes are obtainable.

Substitutions of a single hydrogen atom, or of five hydrogen atoms should produce only one form, and this also accords with the observed facts.

The graphic formula shows that benzene contains six latent valencies, and as a result it is capable of acting as a hexad, though ordinarily it acts as a saturated molecule. The condition when these valencies are developed is easily shown.



Benzene in this condition could take up six atoms of bromin without losing any hydrogen, forming $C_6H_6Br_6$. Such bodies are called additive compounds, are much less stable than the substitutive, and of less importance. Care must be taken not to confound the nomenclature of the two classes of compounds. $C_6H_6Br_6$, an additive compound, would be called benzene hexbromid. C_6Br_6, a substitutive compound in which all the hydrogen has been replaced by bromid, would be hexbromobenzene. Similarly, $C_6H_6(HO)_2$ is benzene dihydroxid, while $C_6H_4(HO)_2$ is dihydroxybenzene.

The following are the principal members of the

BENZENE SERIES.

Name.	Formula.	Freezing point. F.	Boiling point. F.
Benzene	C_6H_6	32	177
Toluene	C_7H_8	Below — 20	231
Xylene	C_8H_{10}	Several isomeric forms of each of these; of different freezing and boiling points.	
Cumene	C_9H_{12}		
Cymene	$C_{10}H_{14}$		

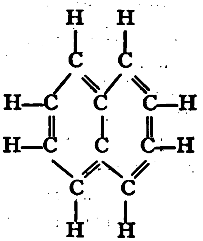
Benzene, C_6H_6, sometimes called *benzol*, may be made in several ways, among which is the destructive distillation of coal. In the manufacture of illuminating gas from coal a quantity of tar is produced, and from this, by *fractional distillation, the* benzene is obtained. When pure, it is a colorless, mobile liquid. It is lighter than water, and insoluble in it; mixes with alcohol and ether, and is very inflammable. It is largely used as a solvent for resins and fats. When treated with strong nitric acid it yields nitrobenzene:

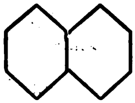
$$C_6H_6 + HNO_3 = C_6H_5(NO_2) + H_2O.$$

Nitrobenzene is a yellow liquid, having an odor which resembles somewhat that of bitter almond oil. It is now used as a cheap perfume, especially in soaps, under the name of *oil of mirbane*. It is distinctly poisonous, producing, even in small doses, unconsciousness, with marked delay in respiration. When nitrobenzene is heated with nascent hydrogen it is converted into *anilin*, $C_6H_5H_2N$. By distilling nitrobenzene with sodium amalgam, azobenzene, $(C_6H_5)_2N_2$, is obtained.

Toluene is methyl benzene, $C_6H_5CH_3$, that is, benzene in which one atom of hydrogen has been replaced by methyl. It is a limpid liquid, lighter than water, and not solidifying at the freezing point of water. It generally exists in crude benzene.

Naphthalene, $C_{10}H_8$, sometimes called coal-tar camphor, is obtained from coal tar, in the form of white, somewhat fragrant, crystalline scales. It melts at 176° F. (80° C.). It is slightly soluble in boiling water. It is used extensively to protect goods against moths. Naphthalene consists of a double ring of carbon atoms saturated with hydrogen; thus,—



The symbol is usually expressed by 

When dissolved in hot, strong sulfuric acid, two isomeric *naphthalenesulfonic acids*, $C_{10}H_7HSO_3$, are formed. From each of these, by the action of potassium hydroxid, an alcohol, $C_{10}H_7HO$, hydroxynaphthol, is formed. These bodies are generally known respectively as α- and β-naphthol. β-naphthol is now much used as an antiseptic. The so-called hydronaphthol is a form of β-naphthol. All the naphthols have antiseptic power, but act often by preventing the growth of bacilli rather than by destroying them.

By the action of oxidizing agents naphthalene is converted into phthalic acid, $H_2C_6H_4O_4$. If this be converted into calcium phthalate, $CaC_6H_4O_4$, and heated with lime for several hours, calcium benzoate, $Ca(C_7H_5O_2)_2$, is formed. These reactions form an important source for benzoic acid.

Anthracene, $C_{14}H_{10}$.—This is obtained from coal tar, being one of the least volatile ingredients. The crude article is a solid, generally of a greenish-yellow color, and a peculiar odor which is not unlike that of a decayed tooth. The pure anthracene is crystalline, and gives a fine blue fluorescence. It melts at 213° C. (415° F.). It is insoluble in water. Its oxidation products are of great importance, because from them may be obtained *alizarin*, a body to which the valuable dye madder owes its color. The artificial production of the madder color has been extensively carried on of late years.

Phenol, hydroxybenzene, C_6H_5HO, is often called carbolic acid, also phenic or phenylic acid. It exists in coal tar, and can also be made artificially by several processes. It forms colorless crystals, is very deliquescent, and soluble in water, melting at 93° F. (34° C.), and boiling at 370° F. (187° C.). It has a peculiar odor, much like that of kreasote. Pure phenol remains unaltered in the air, but the commercial article generally acquires in time a pink tinge. By the action of nitric acid on phenol the complete result is:—

Picric acid, or *trinitrophenol*, $C_6H_2(NO_2)_3HO$, a deep yellow crystalline substance, very soluble in water. It is also obtained when nitric acid acts upon many other substances, as indigo, silk, wool, etc. In the arts it is employed as a dye for silk and wool. It is monobasic, and some of its salts are explosive. Its solution possesses the power of coagulating albumin, and is used as a test for that substance.

Picric acid contains the alcoholic hydroxyl group of phenol, which acquires the function of acid hydroxyl by reason of the presence of three of the powerful negative groups, NO_2.

Dihydroxybenzenes, $C_6H_4(HO)_2$. Three forms, of course, exist: *ortho*, *meta*, and *para*. They are known as:—

Pyrocatechol,	(1.2)
Resorcinol,	(1.3)
Hydroquinol,	(1.4).

Resorcinol is sometimes used as an antiseptic. Hydroquinol is often employed as a developer in photography.

Three trihydroxybenzenes also exist. The consecutive form is pyrogallol (pyrogallic acid) used largely in photography. The symmetric form is phloroglucol (phloroglucin) used in a test for free hydrochloric acid.

Cresol, $C_6H_4(CH_3)HO$, Cresylic Acid.—This has the same relation to toluene, C_7H_8, that phenol has to benzene. Phenol is hydroxybenzene; cresol is hydroxytoluene. It exists in coal tar, which, when pure, crystallizes in white needles, which melt at 36° C. (95° F.). It is often present in commercial phenol.

Kreasote, which is obtained from wood tar, is a mixture of various bodies. Commercial kreasote is often largely phenol.

Orcin, $C_7H_8O_2$, is a product having some of the qualities of an acid, derived from plants known as *lichens*. By oxidation it forms a bright red compound, which is used in dyeing. The same lichens which yield orcin will, by maceration with water, and allowing to ferment, yield a red coloring matter, sparingly soluble in water, and instantly turning blue when neutralized with alkalies. This substance is *litmus*, and is used as a test for the presence of acids and alkalies.

BENZYL COMPOUNDS.

By the substitution of hydroxyl for the hydrogen of methyl in toluene (methyl-benzene), a hydroxid is formed isomeric with cresol. This body (hydroxymethyl-benzene), $C_6H_5CH_2HO$, is known as benzyl alcohol. It forms an aldehyde and an acid by oxidation.

Benzaldehyde, C_7H_6O, is oil of bitter almonds. Its formation from amygdalin by a species of fermentation is pointed out elsewhere. It is a colorless liquid, heavier than water, and, as usually made, has the smell of hydrogen cyanide, since that body is formed from amygdalin at the same time as the oil. Oil of bitter almonds has been used in confectionery as a flavor. It is sometimes substituted by nitrobenzene.

Benzoic acid, carboxybenzene, $C_6H_5(COOH)$, occurs in various resins, especially in *benzoin*. It is sometimes found in the urine of herbivora, and can be made artificially by several methods. One of these is given under naphthalene; another is described under hippuric acid. Benzoic acid is a white crystalline solid, of pleasant odor, but very disagreeable taste. It dissolves but slightly in cold water, but more so in hot water and alcohol. It sublimes at a temperature below its boiling point.

Salicylic, orthohydroxy-carboxy-benzene, $C_6H_4(COOH)(HO)$, differs, in empirical formula, from benzoic acid in having an additional atom of oxygen, hence it is sometimes called oxybenzoic acid. It is, however, not made from benzoic acid, but from the action of carbon dioxid, on a mixture of sodium phenate. The reaction is:—

$$\underset{\text{Sodium Phenate.}}{NaC_6H_5O} + CO_2 = \underset{\text{Sodium Salicylate.}}{NaC_7H_5O_3}.$$

Sodium salicylate can also be obtained by the action of sodium hydroxid on salicin.

Salicylic acid forms prismatic crystals, which are sparingly soluble in water. The solution gives a deep violet color with ferric chlorid.

Salol.—Several compounds of the general nature of compound ethers have come into use, lately, with a view of combining the effects of different members of this series. Such is salol, phenyl salicylate, $C_6H_5C_7H_5O_3$, which is supposed to be more active than the acid itself. In the same manner naphthyl salicylate may be prepared.

Saccharin, $C_7H_5NSO_3$.—This is derived from toluene by complex operations. It is a white powder, but slightly soluble in water, and of an intensely sweet taste, from which its common name is derived. It is now used as a substitute for sugar. It has no chemical analogy to common sugar.

Most of these bodies have antiseptic powers; salicylic acid is especially used for preserving beer and various foods. Its use, however, is objectionable.

SUGARS AND STARCHES.

Under this title is included a group of bodies exhibiting strong relationships to each other, and features which distinguish them from most other organic bodies. Moderate deoxidizing power, partial inter-convertibility and susceptibility to alcoholic fermentation, are features which most of them possess. The sugars proper have a sweet taste. They have nearly the same composition and contain only three elements, carbon, hydrogen, and oxygen, the latter two always in the proportion in which they exist in water. Most of these have a decided action on polarized light. The rational formulæ of many of them are now known. They are mostly ketonic or aldehydic in structure, and contain several atoms of asymmetric carbon. They are commonly divided into three classes. In the following list the mark + indicates that the substance rotates a ray of polarized light to the right; — that it *rotates to the left.* Substances unmarked have no action:—

1. SACCHAROSES.	2. GLUCOSES.	3. AMYLOSES.
Sugars Proper.	*Grape Sugars.*	*Starches and Gums.*
$C_{12}H_{22}O_{11}$	$C_6H_{12}O_6$	$C_6H_{10}O_5$
Sucrose (Cane Sugar) +	Dextrose (Grape Sugar) +	Starch +
Lactose (Milk Sugar) +	Levulose (Fruit Sugar) —	Dextrin +
Maltose +	Galactose +	Inulin
	Sorbite +	Gum
	Inosite.	Cellulose.

Sucrose, or *Cane Sugar*, $C_{12}H_{22}O_{11}$, exists in plants, especially sugar-cane and beet. It is extracted by pressure; the liquid is then treated with lime to neutralize free acid, boiled down carefully at a low temperature, the raw product decolorized by animal charcoal and finally crystallized. When heated to 420° F. *caramel*, much used for coloring liquors and confectionery, is formed. By the action of dilute acids, or ferments, or even of heat alone, it is converted into a mixture of equal parts of glucose and levulose, which mixture, on account of the greater effect of the levulose on polarized light, rotates such rays to the left, and is therefore known as *inverted* sugar. Sugar, although freely soluble in water, is almost insoluble in alcohol and ether.

Lactose, or *Milk Sugar*, exists in milk, and has the same composition as cane sugar. It is much less sweet, and less soluble in water. Milk sugar is used as a diluting agent in triturations.

Glucose, $C_6H_{12}O_6$.—This is found in many vegetables, especially ripe fruits, and also in honey. Blood and urine contain small quantities, and the latter fluid, under special conditions, becomes rich in glucose. Glucose exists in two isomeric modifications, dextrose or grape sugar, which turns the ray of polarized light to the right, and levulose, or fruit sugar, which rotates it to the left. Dextrose may be obtained artificially by boiling starch with dilute sulfuric acid, adding chalk, and evaporating the liquid. This process is now carried out on a very extensive scale, the dextrose produced being used to adulterate and substitute cane sugar. It is soluble in dilute alcohol, but is not nearly so sweet as sucrose.

Starch, *Amylose*, $C_6H_{10}O_5$, occurs in many plants. It is a white powder, which is made up of granules of various sizes, having a definite, organized structure, which is different in different plants, so that by means of the microscope the various starches can be distinguished one from another, a point of great importance in reference to food adulteration. These granules are not soluble in cold water, ether, or alcohol, but if heated with water to about 160° F. (72° C.), they swell and break up, yielding a thick mass termed starch paste. Upon boiling this mass with more water, the particles are reduced to such a fine state of division that they will pass through a filter, and when the boiling is continued for some time the solution becomes clear, and the starch soluble. The test for starch is the formation of a deep blue color with free iodin. The extraction of starch may be easily illustrated by grating a potato, and washing the grating in a sieve, which will retain the wood fibre and let the starch granules through as a heavy white powder.

Starch exists in the seeds of grasses, associated with a nitrogenous substance, *diastase*, which has the power to transform the starch into maltose. When the seed germinates this transformation begins, and if the germination be interrupted before the sugar undergoes further change, we have *malt*, which is simply sprouted grain, usually barley. When malt is steeped in water and yeast added, the fermentation of the sugar begins. Glucose is made from starch by the use of sulfuric acid.

Dextrin, $C_6H_{10}O_5$.—This substance is also known as British gum, and may be obtained by heating starch to about 320° F. (160° C.). The change is much more speedily effected by the addition of a little hydrochloric or nitric acid. Dextrin, together with maltose, is formed when malt extract acts upon starch. It is insoluble in alcohol, but very soluble in water, and is used as a mucilage. It is converted into glucose by heating with dilute acids.

Gum Arabic is an exudation from many species of *Acacia*. It consists chiefly of the calcium salt of arabic acid, $CaC_{12}H_{18}O_{10}$. It is used in the preparation of mucilage.

Gum Tragacanth.—This has a composition similar to gum arabic, but is not entirely soluble in water. It absorbs water in large amount and swells up, making an adhesive paste. Many other vegetable gums are known.

Cellulose, $C_6H_{10}O_5$, is the colorless material of woody fibre. It is seen in cotton or linen paper in a nearly pure form. Cellulose dissolves in an ammoniacal solution of cupric hydroxid, but is insoluble in water, ether, or alcohol. Strong sulfuric acid converts it either into a soluble substance, like dextrin, or into a substance, giving a blue color with iodin. By long-continued action of dilute sulfuric acid, cellulose is converted into dextrose.

Paper is cellulose, either obtained from cotton or linen by breaking up the fibre of these by mechanical processes, or made from straw or wood. The *process of making paper* from straw or wood is to boil at about 300° F.

with sodium hydroxid, or by the action of magnesium sulfite on wood; by this means the cementing materials between the fibres are dissolved, and the fibres become loose and soft. When paper is dipped for a few seconds in a cold mixture of two volumes of strong sulfuric acid and one of water, it shrinks and becomes waterproof, constituting *parchment paper*.

Gun-cotton.—When cotton is put into a mixture of equal volumes of strong nitric and sulfuric acids, no apparent change occurs; but after drying it is found to be exceedingly inflammable. A substitution product is here formed, termed *trinitro-cellulose*, in which NO_2 replaces hydrogen, $C_6H_7(NO_2)_3O_5$.

Collodion is formed by dissolving certain kinds of gun-cotton in a mixture of ether and alcohol. This is called *plain collodion*, and is used in surgery. By the addition of various iodids it becomes photographer's collodion. A mixture of collodion with silver bromid in suspension is now much used in photography under the name of emulsion. A mixture of gun-cotton and camphor is called *celluloid*. It is a tough, hard mass, which may be easily softened by heat and then can be moulded into any shape. Mixed with zinc oxid it can be given an appearance resembling ivory; mixed with vermilion it is used as a substitute for vulcanized rubber in teeth-plates.

All the forms of cellulose yield nitro-compounds analogous to gun-cotton. The formula $C_6H_{10}O_5$ is merely an empirical representation of the composition of cellulose. Its structural formula is not known.

Glycogen.—This is a white, amorphous powder, which gives a brown color with iodin, and by the action of ferments or dilute acids it becomes dextrose (dextro-glucose). It therefore resembles starch, but is soluble in water. It is found in the liver of several animals; also in yolk of egg and in some mollusca.

CHEMICAL RELATIONS OF SUGARS AND STARCHES.

The sugars and starches are reducing agents, but not very energetic. The action is generally increased by the presence of strong alkalies. The tests for them are mostly dependent upon their reducing action upon the salts of copper, silver, bismuth, and mercury. Glucose is the most active in this respect, and the other members of the class may generally easily be converted into glucose before being tested.

GLUCOSIDS.—This term includes a large number of bodies, mostly obtained from plants, and possessing the quality of being easily decomposed into several distinct substances, one of which is glucose. Dilute acids and ferments are the usual means of producing this specific decomposition.

They may be regarded as compound ethers, derived from glucose. They are sometimes quite complicated in composition, generally have marked medicinal qualities, and often, therefore, constitute the active principles of the plants from which they are obtained. Some of them are associated with a body capable of acting as a ferment, and thus are decomposed as soon as exposed to heat and moisture, which causes the ferment to act.

Starch and most of the amyloses may be glucosids, since they yield glucose by the action of acids and ferments.

Amygdalin, $C_{20}H_{27}NO_{11}$, exists in seeds of many plants of the order Rosaceæ, in association with a ferment called *synaptase*. This acts on the amygdalin, when the seeds are crushed in cold water; but boiling alcohol coagulates the synaptase and dissolves the undecomposed amygdalin. The latter is a white, crystalline body, soluble in alcohol and water, but not in ether. The decomposition to which it is susceptible is explained in connection with the description of hydrogen cyanid.

Salicin, $C_{13}H_{18}O_7$, is found principally in the bark and leaves of the Poplar and Willow. It crystallizes in white needles; insoluble in ether, but soluble in water and alcohol. Salicin decomposes as follows:—

$$C_{13}H_{18}O_7 + H_2O = C_7H_8O_2 + C_6H_{12}O_6.$$

$C_7H_8O_2$ is called *saligenin*.

Tannins.—These are astringent principles, widely diffused in the vegetable kingdom. They dissolve in water and have an acid reaction; hence are often called tannic acids. They present numerous varieties, which possess the common property of forming insoluble compounds with gelatin, and giving dark-colored precipitates with ferric salts. Their action on gelatin is taken advantage of in the preparation of leather; while by their action with ferric salts common ink is made.

Ordinary tannin or *gallo-tannic acid* occurs in nutgalls—excrescences formed on a species of oak by puncture by an insect—and sumach. It is usually seen as a loose, brittle, light-yellow, non-crystalline mass, very soluble in water and highly astringent. It gives a bluish-black precipitate with ferric salts. The common form is not entirely a glucosid, but contains a large amount of digallic acid, $C_{14}H_{10}O_9$.

When tannin is boiled with dilute acids, or mixed with water and exposed to moist air, it forms gallic acid. The gallic acid may come either from the splitting up of the glucosid or the absorption of water by digallic acid:

Thus:—

$$\overset{\text{Tannin (glucosid).}}{C_{27}H_{22}O_{17}} + 4H_2O = \overset{\text{Glucose.}}{C_6H_{12}O_6} + \overset{\text{Gallic Acid.}}{3C_7H_6O_5}.$$

$$\overset{\text{Digallic Acid.}}{C_{14}H_{10}O_9} + H_2O = \overset{\text{Gallic Acid.}}{2C_7H_6O_5}.$$

The conversion of tannin into gallic acid is one of the sources of loss in the manufacture of leather, since gallic acid has no tanning qualities. The change can be prevented by antiseptic substances, such as sulfurous and boric acid, and solutions of these are now sold under the name of *antigalline*. The process of tanning consists essentially in the tannin rendering the gelatinous matter of the hide insoluble, and therefore not liable to decomposition.

Solanin, $C_{43}H_{71}NO_{16}$, exists in plants of the order *Solanaceæ;* for instance, in the young shoots of the potato.

MYRONIC ACID, $C_{10}H_{19}NS_2O_{10}$.—The seed of the Black Mustard contains potassium myronate, which is decomposed by an albuminous ferment contained in the mustard seed into allyl thiocyanate, glucose, and acid potassium sulfate. Thus:—

$$KC_{10}H_{18}NS_2O_{10} = C_2H_5CNS + C_6H_{12}O_6 + KHSO_4.$$

The allyl thiocyanate is the substance which gives to mustard its medical virtue, and as hot water would coagulate the albuminous ferment, and thus prevent the reaction, mustard plaster must be made with cold water. White mustard seed contains a glucosid, *sinalbin*, and a ferment, *myrosin*.

Indican, $C_{52}H_{62}N_2O_{34}$, occurs in several plants, especially those of the genus *Indigofera*. By boiling with acids it yields the color known as *indigo blue* (indigotin). Indigo blue is obtained from the plants containing indican, by macerating them with water, and exposing to the air until fermentation ceases. The blue is deposited, and is formed into cakes, which have a copper lustre when rubbed. Indigo is insoluble in water, but by action of nascent hydrogen it takes up two atoms of that element; it is converted into a soluble white powder. By exposing this to the air it again becomes the insoluble blue color. These reactions are taken advantage of in dyeing with indigo, the cloth being steeped in solution of white indigo and then exposed to the air. Indigo blue forms several compounds with strong sulfuric acid, which are generally known in commerce as *sulfate of indigo*.

COMPOUNDS CONTAINING NITROGEN.

These are numerous and of many grades of complexity, from bodies like cyanogen, CN, up to those which form the tissues of plants and animals. Nitrogen may combine with hydrogen or other positives, may replace hydrogen, or may act in combination with oxygen; in all these conditions it gives rise to series of bodies of essentially different character. Carbon and nitrogen form the cyanogen series. Carbon, hydrogen, and nitrogen form a group—including many purely artificial products—having alkaline characters. Carbon, hydrogen, nitrogen, and oxygen form groups, including most of the principles upon which the medicinal virtue of plants depend, and many of the materials forming the tissues of animals and plants. Nitrogen and oxygen, in combination, in the proportion NO_2, constitute a monad radicle, which can easily substitute hydrogen, and thus give rise to a series of artificial substances, of which the chief characteristic is their explosive qualities.

CYANOGEN AND DERIVATIVES.

Nitrogen and carbon do not combine if brought in contact, but if a current of nitrogen be passed over a mixture of carbon and potassium carbonate, *potassium cyanid*, KCN, is formed. From this, other cyanids may be obtained. By heating mercuric cyanid, $Hg(CN)_2$, free cyanogen, C_2N_2, is formed. It is a colorless, poisonous gas. It combines with both positive and negative bodies. In writing the formulæ of bodies containing cyanogen, the symbol CN is often abbreviated to Cy.

Two forms of cyanogen compounds are known, termed respectively the cyanids and isocyanids, as follows:—

Potassium Cyanid.	Potassium Isocyanid.
$\text{K}-\text{C}\equiv\text{N}$	$\text{K}-\text{N}\mathrel{\substack{\textstyle =\\ \textstyle =}}\text{C}$

It will be noticed that in the former the nitrogen is triad and in the latter pentad.

Potassium Cyanid, KCN.—This body, prepared usually by decomposing some more complex cyanids, is a snow-white mass, very soluble in water, and easily decomposed even by the carbonic acid of the air, hydrogen cyanid being formed. Potassium cyanid dissolves most of the salts of silver which are insoluble in water, except silver sulfid. It is used in silver plating and in photography, also in very small doses as a medicine. It is a powerful poison. It can be melted without change, but in the presence of air or oxidizing agents it becomes potassium cyanate, KCNO.

Hydrogen Cyanid, HCN.—This is generally called hydrocyanic or prussic acid. When pure, it is a colorless liquid, easily decomposed and intensely poisonous, a drop or two producing death in a few moments. As sold for medical purposes it is very dilute, consisting of two parts of acid to ninety-eight of water. It has, even when much diluted, a strong odor of bruised peach kernels. In fact, hydrogen cyanid is formed from these substances by the decomposition of nitrogenous principles when the seeds are crushed with cold water. This occurs under the influence of special ferments, for if these are first coagulated by boiling alcohol, no decomposition occurs. The reaction by which hydrogen cyanid is formed when bitter almonds are macerated with water consists in the breaking up of a crystalline principle called amygdalin, under the fermenting influence of a nitrogenous body called synaptase, as follows:—

$$\overset{\text{Amygdalin.}}{C_{20}H_{27}NO_{11}} + 2H_2O = \overset{\text{Benzal-dehyde.}}{C_7H_6O} + \overset{\text{Hydrogen Cyanid.}}{HCN} + \overset{\text{Glucose.}}{2C_6H_{12}O_6}.$$

Hydrogen cyanid may also be made by decomposing other cyanids by strong acids, thus:—

$$2KCN + H_2SO_4 = K_2SO_4 + 2HCN.$$

Double Cyanids.—The cyanids of the potassium group show a great tendency to combine with other cyanids, especially those of the iron group, to form double cyanids, in which some of the properties of the single cyanids, especially the poisonous qualities, are much diminished. The iron series is the most important. We distinguish two well-marked compounds.

Potassium ferrous cyanid, $FeCy_2 + 4KCy$, usually called *potassium ferrocyanid*, and written K_4Cy_6Fe, is generally made by heating a mixture of nitrogenous organic matter, iron scraps, and potassium carbonate, treating the mass with water and allowing it to crystallize. Large lemon-yellow crystals are formed, which are not poisonous. They are much used by the arts, under the name of yellow prussiate of potash. Oxidizing agents convert the ferrous cyanid into ferric, and produce a body called—

Potassium ferric cyanid, $Fe_2Cy_6 + 6KCy$, commonly called *potassium ferricyanid* or red prussiate of potash. It forms large ruby-red crystals, soluble in water. From these others may be obtained. The reactions with some substances are so distinct as to constitute very delicate tests. With ferrous compounds, for instance, the ferricyanids give a dark-blue precipitate; ferric salts give, with ferrocyanids, a similar blue precipitate—Prussian blue. The two precipitates are nearly identical in composition. An intermediate compound is known as *soluble* Prussian blue, being soluble in pure water, but insoluble in water containing various salts. The true Prussian blue is dissolved by alkalies, but not by acids, except oxalic; a solution made with this acid is used as a blue ink. Prussian blue is much used as a substitute and adulterant of indigo, and for coloring green teas. No precipitate is produced by the action of ferricyanids on ferric salts. That produced by the action of ferrocyanids on ferrous salts is white, but is quickly converted into the blue form by oxidation.

Tests for Cyanids.—The recognition of cyanogen is a matter of importance in toxicology. The tests can be satisfactorily applied only to the simple cyanids; the double cyanids usually give the reactions after being decomposed by acids.

Silver nitrate gives a white precipitate of silver cyanid, which is soluble in boiling nitric acid.

A mixture of ferrous sulfate and sodium hydroxid, when agitated with a cyanid and then treated with acid, will produce a blue precipitate.

When hydrogen cyanid is brought into contact with ammonium sulfid, a compound called ammonium thiocyanate is formed, which gives, with ferric chlorid, a blood-red color.

Cyanates.—Cyanogen being a monad radicle, a single molecule cannot saturate completely the members of the oxygen group, and the compound CNO is, therefore, also a monad radicle. There are two forms of these derivatives, cyanates and isocyanates, corresponding to the cyanids and isocyanids. Several polymeric isomers of these compounds are known. The potassium series is:—

$KCNO$	Potassium cyanate.
$K_2C_2N_2O_2$	Potassium fulminate.
$K_3C_3N_3O_3$	Potassium cyanurate.

A large number of derivatives have been obtained from these bodies, but only a few are important.

Ammonium Cyanate, NH_4CNO.—This is one of the most interesting of the derivatives of this class, because it is identical in composition with urea, the most abundant solid constituent of the urine, and may be easily converted into it. It may be formed by the action of ammonium sulfate on potassium cyanate, and when heated, either in the solid state or dissolved, it soon becomes converted, without change of composition, into a body from which neither cyanic acid nor ammonium can be obtained by the usual tests. This fact shows that the atoms have been rearranged. The body, in fact, has been converted into a substitution ammonium compound, and is identical with urea as obtained from urine.

Sulfur may substitute oxygen, and thus give rise to a series of *thiocyanates* and *isothiocyanates*.

Potassium thiocyanate, KCNS, is a white, crystalline body, very soluble in water, producing with ferric salts a deep blood-red color, which is utilized as a delicate test. Ammonium thiocyanate, NH_4CNS, is formed when hydrogen cyanid acts on ammonium sulfid, which contains some free sulfur. The reaction is $(NH_4)_2S + S_2 + 2HCN = 2NH_4CNS + H_2S$. It is the basis of one of the tests for cyanogen.

SUBSTITUTION AMMONIUMS.

Amin, NH_3, ammonia, is always found, either free or combined, among the products of decomposition of nitrogenous matter. As a distinct substance, one of its most striking properties is its power to neutralize acids. When certain organic bodies containing nitrogen were found to have a similar property, a similar constitution was assigned to them. Morphin, quinin, etc., which, like amin, are decidedly alkaline, and contain considerable nitrogen, have been regarded as ammoniacal in character. Although efforts to produce these bodies artificially have succeeded only to a limited extent, yet many substances resembling them in composition have been obtained, and no doubt need now exist as to the essential nature of these products, or as to the possibility of ultimately producing them. Many of the artificial bases now known are produced by the substitution of the hydrogen or nitrogen in amin, NH_3, or ammonium, NH_4, by other elements or radicles. The number of compounds so produced is greatly increased by the fact that these molecules are capable of polymerism, that is, duplicating themselves, so that one set of compounds may be formed on the type NH_3, and another on that of N_2H_6, and so on. A very complete and systematic nomenclature has been adopted for these compounds. In the first place, the character of the replaceable radicles, and, to a certain extent, therefore, the character of the compound itself, is indicated by the termination. When the radicle is positive, and especially when it does not contain oxygen, "*in*" is used; when negative, and containing oxygen, "*id*" is used. When the nitrogen is replaced by some member of its group (B, P, As, Sb, and Bi), some distinct syllables of these names are added. The names of all the radicles entering into the compound are attached. If the molecule is duplicated, the syllables "*di*," "*tri*," etc., are used to indicate the degree of duplication.

If the compound is derived from the type NH_4 it has the termination "onium." The following list will show all these points:—

NH_3, amin; N_2H_6, diamin; N_3H_9, triamin; N_4H_{12}, tetramin.
PH_3, phosphin; P_2H_6, diphosphin.
AsH_3, arsin.
SbH_3, stibin.
NH_4, ammonium; N_2H_8, diammonium; N_3H_{12}, triammonium.
PH_4, phosphonium.
AsH_4, arsonium.
SbH_4, stibonium.

The consolidation of the molecules into diamins and triamins takes place under the influence of radicles of dyad, or higher valency. The methods of producing these substitution compounds are various; one of the simplest is by heating solutions of amin with bromids or iodids of the radicles to be substituted. Thus, if amin and ethyl iodid be heated for some hours in a sealed tube, we have the reaction—

$$NH_3 + (C_2H_5)I = (C_2H_5)H_3NI.$$

As NH_4I is ammonium iodid, so the above compound is called ethyl-ammonium iodid. By further action the whole of the hydrogen may be replaced by ethyl, and we get $(C_2H_5)_4NI$, tetrethyl-ammonium iodid. Each of the hydrogen atoms may be replaced by a different radicle, and thus great complexity in structure and nature arises. Thus:—

$(C_2H_5)_2(C_5H_{11})HNI$, ... diethyl pentyl ammonium iodid.
$(C_2H_5)_3(C_5H_{11})NI$, ... triethyl pentyl ammonium iodid.
$(CH_3)(C_2H_5)(C_3H_7)(C_4H_9)NI$, . methyl ethyl trityl tetryl ammonium iodid.

From NH_3 we may derive—
$(C_2H_5)H_2N$, ... ethylamin.
$(C_2H_5)_2HN$, ... diethylamin.
$(C_2H_5)_3N$, ... triethylamin.

When but one-third of the hydrogen is substituted, the body is said to be *primary;* when two-thirds are substituted, it is *secondary;* when all is substituted, the body is *tertiary.* Ethylamin, for instance, is a primary monamin.

Diamins and diammoniums. These always contain N_2:—

$(C_2H_4)H_4N_2$, ... ethene diamin.
$(C_2H_4)H_6N_2(HO)_2$, . . . ethene diammonium hydroxid.

Triamins, and triammoniums, tetramins, and tetrammoniums, are formed on the same principle.

The following formulæ show some of the compounds obtained by these elaborate substitutions, especially when the nitrogen is replaced by other members of its group:—

Ethyl Phosphin.
$(C_2H_5)H_2P$

Diethyl Phosphin.
$(C_2H_5)_2HP$

Triethyl Phosphin.
$(C_2H_5)_3P.$

Trimethyl Arsin.
$(CH_3)_3As.$

Tripentyl Stibin.
$(C_4H_{11})_3Sb.$

Triethyl Bismin.
$(C_2H_5)_3Bi.$

Triethyl Borin.
$(C_2H_5)_3B.$

Tetrethyl Phosphonium Hydroxid.
$P(C_2H_5)_4HO.$

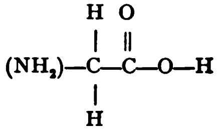
Tetrethyl Stibonium Iodid.
$Sb(C_2H_5)_4I.$

By a combination of radicles of different valencies, we may get such a body as—

$(CH_3)_3(C_2H_5)_3(C_2H_4)H_4P_3I_3$, trimethyl-triethyl ethene triphosphonium iodid.

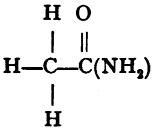
AMIDS.—All primary monamins may be expressed as substitutions of amidogen, NH_2, for other monads. When the amidogen is associated with a substantially positive group, the compound is basic, and is properly called an amin, but when associated with negative groups it may form either acid or neutral bodies which are properly called amids. Thus, amidogen may be substituted for the hydrogen of benzene, giving rise to $C_6H_5NH_2$, amidobenzene, which is basic, and is therefore an amin. Substituted for the hydrogen of acetic acid it gives amido-acetic acid, in which some of the acid properties are retained, but substituted for the hydroxyl of acetic acid it entirely removes the acid function, forming a body called acetamid. These facts are shown by graphic formulæ:—

Amido-acetic Acid.



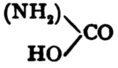
$$\begin{array}{ccccccc} & & H & & O & & \\ & & | & & \| & & \\ (NH_2) & — & C & — & C & — & O—H \\ & & | & & & & \\ & & H & & & & \end{array}$$

Acetamid.

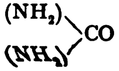


$$\begin{array}{ccccc} & & H & & O \\ & & | & & \| \\ H & — & C & — & C(NH_2) \\ & & | & & \\ & & H & & \end{array}$$

Amido-carbonic Acid.



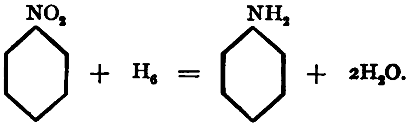
Carbonyldiamid (Urea).



The hydrogen of the amidogen or of the other radicles may be replaced by equivalent bodies.

The majority of the substances indicated in outline, in the preceding paragraphs, are purely products of the laboratory, but some of them are identical with natural products. Many natural products are so analogous in composition and properties to the amins, diamins, etc., that no doubt can exist as to their similar nature. A few of these substitution compounds, the exact composition of which is known, will be noticed.

Anilin, Phenylamin, Amidobenzene, $(C_6H_5)H_2N$.—This body is made by the action of nascent hydrogen on nitrobenzene:—



Anilin is a liquid, boiling at 360° F. (182° C.). It is an active poison. By the action of oxidizing agents of different powers it becomes converted into bodies of complicated composition, some of them triamins, having coloring powers of great beauty and variety, the production of which has given rise to an extensive industry. It appears that, for producing most of these colors, the perfectly pure anilin will not answer; that made from crude nitrobenzene is always used.

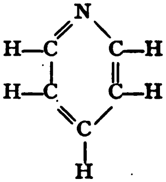
Toluidin, $(C_7H_7)H_2N$.—There are three isomeric modifications of toluidin, which differ in their fusibility and boiling point. The presence of toluidin in anilin is necessary to fit the latter for the production of some of the anilin colors.

Rosanilin, $(C_7H_6)_2(C_6H_4)H_3N_3$, is a triamin base, which forms with acids a series of highly-colored salts, extensively used in dyeing.

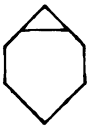
Trimethylamin, $(CH_3)_3N$, occurs in many plants, as in the flowers of the hawthorn and the pear tree, and in wormseed, as well as in different animal liquids. It is a colorless gas, boiling at 48.7° F. (9.3° C.) and smelling of amin and fish brine.

Acetanilid, $NHC_6H_5C_2H_3O$, *Antifebrin.*—This is acetamid in which one atom of hydrogen in the amidogen has been replaced by the radicle C_6H_5. It is a white crystalline powder, not basic. It is used as an antipyretic.

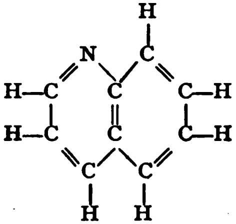
Pyridin and Derivatives.—In addition to the basic substances derived from amin, many are now known which contain a closed chain arrangement of the carbon atoms analogous to that observed in the benzenes. The type of the series is pyridin, C_5H_5N, a product of the destructive distillation of bones. Its structural formula is expressed thus :—



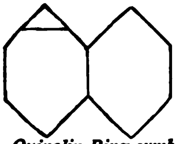
The pyridin ring may be conveniently indicated by Armstrong's system. thus:



Substitution compounds are indicated acccording to the rule given under benzene. A double ring, consisting of a benzene ring joined to a pyridin ring, exists in a compound known as quinolin, and also gives rise to a series of derivatives.



Quinolin.



Quinolin Ring-symbol.

These arrangements of the carbon atoms resist the action of chemical agents even better than that in benzene and its derivatives.

LIST OF IMPORTANT ALKALOIDS.

NAME.	FORMULA.	SOURCE.	PROPERTIES, ETC.
Nicotin, . . .	$C_{10}H_{14}N_2$	Tobacco. (*Nicotiana tabacum.*)	Liquid; boils at 464° F. (240° C.). Sp. gr. 1.027. Soluble in water.
Conin, . . .	$C_8H_{17}N$	Water hemlock. (*Conium maculatum.*)	Liquid; boils at 414° F. (212° C.). Sp. gr. 0.89. It has been prepared artificially.
Lobelin, . . .		Indian tobacco. (*Lobelia inflata.*)	Liquid.
Sophorin, . .		*Sophora Japonica.*	Liquid.
Morphin, . .	$C_{17}H_{19}NO_3$	Opium.	Crystals; slightly soluble in water.
Codein, . . .	$C_{16}H_{21}NO_3$	"	Octahedral crystals; more soluble in water than morphin.
Narcotin, . .	$C_{22}H_{23}NO_7$	"	Crystals; nearly insoluble in water.
Apomorphin, .	$C_{17}H_{17}NO_2$	By heating morphin with HCl, to about 300° F. (150° C.).	Is distinguished by being emetic, instead of narcotic.
Quinin, . . .	$C_{20}H_{24}N_2O_2$	Cinchona bark.	These alkaloids are principally distinguished by their action on polarized light. Quinin, cinchonidin, and cinchonicin turn the plane of polarization to the left; Cinchonin, quinidin, and quinicin, to the right. They are—except quinoidin, which is a resinous mass—crystalline bodies, not very soluble in water. Two bodies isomeric with quinin have been prepared artificially, but neither is identical in properties with the natural alkaloid.
Quinidin, . .	"		
Quinicin, . .	"		
Quinoidin, .	"		
Cinchonin, . .	$C_{20}H_{24}N_2O$		
Cinchonidin, .	"		
Cinchonicin, .	"		

Hyoscyamin, .	$C_{15}H_{23}NO_3$	*Hyoscyamus niger.*	These are the active principles of well-known and important medicinal herbs. They are all powerful poisons. Atropin is noted for its power of dilating the pupil.
Atropin, . . .	$C_{17}H_{23}NO_3$	*Atropa belladonna.*	
Homatropin, .	$C_{16}H_{22}NO_3$	From Atropin.	
Aconitin, . . .	$C_{30}H_{47}NO_7$	*Aconitum napellus.*	
Veratrin, . . .	$C_{32}H_{52}N_2O_8$	*Veratrum sabadilla.*	
Colchicin, . .	$C_{17}H_{19}NO_5$	*Colchicum autumnale.*	
Strychnin, . .	$C_{21}H_{22}N_2O_2$	Nux vomica.	They form white crystals. Strychnin is less soluble than brucin.
Brucin, . . .	$C_{23}H_{26}N_2O_4$		
Caffein, . . .	$C_8H_{10}N_4O_2$	Coffee.	Soluble in water; basic properties feeble.
Thein, . . .	"	Tea.	" " " " "
Cocain, . . .	$C_{17}H_{21}NO_4$	Coca leaves.	Soluble in water. Local anesthetic.
Theobromin, .	$C_7H_8N_4O_2$	Cacao.	Crystals; not very soluble in water.
Piperin, . . .	$C_{17}H_{19}NO_3$	Cayenne pepper.	*Yellow* crystals; insoluble in water. Isomeric with morphin, but entirely different in properties.
Pilocarpin, . .	$C_{11}H_{16}N_2O_2$	Jaborandi.	This alkaloid is distinguished by its power to increase the perspiration.
Pelletierin, . .	$C_8H_{13}NO$	Pomegranate root.	Liquid; boils at 360° F. (180° C.).
Physostigmin (Eserin), . .	$C_{30}H_{21}N_3O_4$	Calabar bean.	Produces contraction of the pupils.
Xanthin, . . .	$C_5H_4N_4O_2$	In urine.	Non-crystalline, and but sparingly soluble in water.
Urea, ...	CH_4N_2O	"	Can be prepared from ammonium cyanate, as elsewhere explained.
Kreatinin, . .	$C_4H_7N_3O$	In urine and juice of flesh.	

ALKALOIDS.

The *natural bases or alkaloids* are so called because of their power to neutralize acids, and form with them distinct and crystallizable compounds. They contain carbon, hydrogen, and nitrogen, and many of them, also, oxygen. Their resemblance to the substitution amins is obvious, but they are more complex in constitution, especially as regards the presence of oxygen, which is not an ingredient of the common substitution amins. In this respect the alkaloids agree with the amids. Many of the alkaloids are derived from the pyridin and quinolin groups.

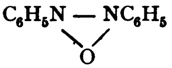
As regards the general properties of the alkaloids, they are mostly solid bodies, not very soluble in water, but soluble in alcohol and easily crystallized. Many have a bitter taste, and decided physiological properties, and are the ingredients upon which the medicinal activity of the plants containing them depends. A few of them are liquid at ordinary temperatures, and those that are solid can be volatilized, without decomposition, by careful heating.

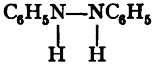
The majority of the alkaloids form salts by directly uniting with the acid, not by substituting the hydrogen. Thus, morphin forms with hydrochloric acid the compound $C_{17}H_{19}NO_3HCl$; it is, therefore, called morphin hydrochlorid, not morphin chlorid. We can understand the fact, however, when we recollect that the alkaloids are analogous to NH_3, rather than to NH_4, and the reaction with morphin and HCl is similar to the reaction, $NH_3 + HCl = NH_4Cl$, in which the hydrogen is not replaced. In fact, we might regard the hydrogen of the acid as combining with the morphin, and form a new molecule, $C_{17}H_{19}NO_3H$, analogous to ammonium and called *morphium;* the compound formed would be *morphium chlorid.*

A number of artificial alkaloids or allied compounds have lately come into prominence in therapeutics. These bodies possess the specific power of reducing the animal temperature, and are collectively known as *antipyretics.* They have generally been given trade names which are either abbreviations of their systemic names or are purely arbitrary. The more important are here briefly described.

Antipyrin, $C_{28}H_{18}N_4O_2$.—This is the trade term of a derivative of quinolin, the full name of which has been given as dimethyl-oxy-quinizin. It is soluble in water and somewhat bitter.

Phenacetin, $C_{10}H_{13}NO_2$.—This is a complex substitution compound, related to antipyrin. Its systematic name is *para-acet-phenetedin.* It is a white, inodorous, tasteless substance, but slightly soluble in water, easily soluble in alcohol.

Azo-Compounds and Derivatives.—When two atoms of nitrogen are joined by two bonds, and the remaining bonds are joined to similar radicles, a group is formed called an azo-compound. Thus, $C_6H_5N = NC_6H_5$, is azo-benzene. When the radicles are dissimilar, as in the group $C_6H_5N = N—O—H$, a diazo-compound is formed; in this case diazo-benzene hydroxid. When an atom of oxygen is inserted between the nitrogen atoms, an azoxy-compound is formed.  $C_6H_5N — NC_6H_5$ (with $\searrow\swarrow$ O below) is azoxy-benzene. When one bond of each nitrogen atom is united to an atom of hydrogen, the body is called a hydrazo-compound.



$$C_6H_5\underset{H}{N}—\underset{H}{N}C_6H_5$$ is hydrazo-benzene.

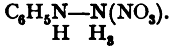
Hydrazins.—The hydrazins agree with the diazo-compounds in containing dissimilar radicles, but differ in the fact that the union between the nitrogen is by one bond only.

The difference may be represented in the following formulæ:—

Diazo-benzene Nitrate.

$C_6H_5N = N—(NO_3)$.

Phenyl-hydrazin Nitrate.



$$C_6H_5\underset{H}{N}—\underset{H_3}{N}(NO_3).$$

Many forms and more complex derivatives of the above bodies exist, and valuable practical applications have been made of the theoretical principles exemplified in their formation.

PTOMAÏNS AND LEUCOMAÏNS.

The organic bases first discovered were almost entirely derived from the vegetable kingdom, especially from the more characteristic flowering plants. The progress of research has shown that such substances are by no means peculiar to that division of organized beings, but that animal organisms and the most minute forms of life are also constantly producing basic nitrogenous bodies. It is now well understood that with the exception of some special transformations under the influence of non-organized ferments, such as diastase, fermentation and putrefaction are caused by the growth of micro-organisms, these deriving their nutriment largely from such nitrogenous matter and phosphates as may be present in the surrounding medium. They convert much of the organic material into simpler compounds. The products formed vary with the nature of the organism. The same rule holds with regard to the larger species of animals and plants, but an important practical difference is noted with regard to the disposition made of the products of the decompositions. The higher forms of animals live principally in the air, and are provided with elaborate excretory organs, by which all products, solid, liquid, or gaseous, can be promptly removed. The higher plants are capable of removing only the gaseous or volatile liquid products. Solids and non-volatile liquids are retained. When, however, the organism lives in a watery medium, the ordinary action of diffusion will cause the removal of most secretions formed within the body. It follows, therefore, that while in the higher animals, and also in microörganisms, the products of vital action will be continually excreted and mingle with the surrounding medium, the similar products in plants will be continually stored in some part of the structure. Thus, such oxalic acid as may be formed in the animal system by the oxidation of organic matter will be excreted in the urine, appearing, generally, as calcium oxalate, while the same product in a vegetable will be found deposited in the substance of the leaves.

The recognition and isolation of the individual substances produced during the growth of microörganisms have only been attained within a few years, and many points still remain to be elucidated. To the basic bodies so formed the general term "ptomaïn" has been applied, while those produced in animals by systemic, physiological, or pathological processes are called "leucomaïns." From what has been said above, however, it will be seen that alkaloids, ptomaïns, and leucomaïns are all substantially the same in nature, the differences depending largely upon the conditions under which the bodies are produced. The ptomaïns proper are often unstable, and those first formed are decomposed by the microörganisms which develop during the later stages of the decomposition. Several important ptomaïns have been isolated. One of the most interesting examples is that discovered by Dr. Vaughan as a product of the incipient decomposition of milk. This was called by him "tyrotoxicon," but by further investigation he has identified it with diazo-benzene. Brieger has found that the organism peculiar to tetanus will, when growing in a proper culture-medium, develop a substance which he has called "tetanin," which will produce the symptoms of tetanus when injected into an animal. The poisonous action of animal food when slightly stale or in incipient decay is to be ascribed to the formation of ptomaïns; for instance, the gastric and intestinal disturbances often produced by milk and cheese have been shown to be due to diazo-benzene compounds produced during incipient decomposition as noted above.

Vaughan has recently pointed out that marked differences exist between the ptomaïns formed during decompositions taking place in the presence of oxygen (aërobic) and those occurring in the absence of oxygen (anaërobic). The latter condition exists in buried corpses, and some of the ptomaïns produced under such circumstances exhibit reactions closely simulating those of the common vegetable poisons, especially morphin.

These basic products of decomposing organic matter have attracted special attention on account of their toxic character and the bearing that their production has upon the causation of disease and on medico-legal questions concerning poisoning by the alkaloids proper. There is, however, nothing peculiar about the group as a product of the growth of microörganisms. All the groups of organic bodies are represented in such action.

Different species of microörganisms may produce alcohols, acids, neutral substances, phenol and its derivatives, etc. The term ptomaïn is derived from a Greek word meaning a dead body, and following out the analogy we might apply the same term to all the products of the decomposition of organic bodies under the influence of microörganisms, distinguishing the different classes by the proper terminations. Thus, we would have ptomols, which would be the alcohols produced by such action, ptomic acids, etc. Lactic and butyric acids are ordinarily produced by the action of microbes, and are therefore ptomic acids. Common alcohol is a ptomol.

It is to be noted, therefore, that the ptomaïns are not peculiar as a class among the basic organic bodies, nor are they the only products of decomposing actions.

BIOLOGIC CHEMISTRY.

Biologic Chemistry is the study of the processes of animal and vegetable life. Both forms of life require for their maintenance solid and liquid food, and processes of respiration, by which gases are absorbed and evolved.

VEGETABLE CHEMISTRY.

Plants take their food in the form of unorganized material, and it is distributed in great part by diffusion, as they do not possess a circulatory system. They are also apparently without any central nervous control, although some plants show irritability and contractility to a high degree. The general nature of vegetable action will be understood by the following sketch of the growth of a plant.

The seed contains an embryo plant, generally with starch. When placed in the soil the embryo begins to grow and the starch is converted into sugar.

This serves as nourishment until the roots are sufficiently developed to get the nourishment from the soil. Experience has shown that good soil contains in soluble form potassium and ammonium compounds, nitrates and phosphates. These the plant takes up by its roots, while the leaves carry on, under influence of light, a process of feeding by which carbon is absorbed and oxygen thrown out. At the same time the leaves perform a respiratory function by which oxygen is absorbed and carbon dioxid exhaled. This process is independent of light. The plant thus continually grows. Warmth and moisture are necessary for these conditions. The final operation of plant life is the production of the fruit. The acids are also partly oxidized as the ripening proceeds. After the fruit is ripe it is liable to die and rot. This growth of the plant is accompanied by the production of different proximate principles. The most important of these are *cellulose*, which constitutes the main framework of all vegetable structure; *starch*, which is deposited in an organized form, and *sugar*, which, being soluble, is found in solution in the fluids. Other proximate principles of plant life are resins, fixed and volatile oils, waxes, glucosids, and alkaloids. Many of these are excretions. The proximate principles of plants are frequently non-nitrogenous. The nitrogen of plants is largely in the seed.

Chlorophyl.—This term is applied to the substance which gives the green color to plants. It has been much studied, but as yet its composition cannot be said to be definitely made out. Its formation in plants, it is well known, is best seen in the leaves and young stems, especially the former. Light is required for its production, because if plants grow in the dark they remain colorless; but as soon as light is admitted to these colorless structures, the secretion of chlorophyl begins and the plants acquire a green color. It appears also to have some relation to the process of nutrition and respiration, for many plants which are true parasites, that is, live on the elaborated juices of other plants, are either nearly colorless, or have colors different from chlorophyl. A familiar example of this is the *dodder*, a parasitic plant allied to the Morning Glory. It twines around succulent stems, penetrates into their substance and extracts the nutritive juices. As soon as it gets a firm attachment, the parasite loses all connection with the soil and lives entirely upon its host. It never forms chlorophyl; the stem remains of a bright orange color, the flowers are white, and the leaves are not developed. In a considerable number of parasitic plants the leaves are rudimentary. According to some authorities chlorophyl consists of two distinct substances, one of which—cyanophyl—is blue and soluble in ether, the other—xanthophyl—is yellow and insoluble. This opinion, however, is opposed by other observers, who regard the two forms as decomposition products. No definite information can be given as to the chemical nature of the well-known changes which occur in autumn. Some have supposed, as mentioned above, that the green color was due to the mixture of yellow and blue substances, and that the blue decomposed most easily, leaving the yellow, but this is not proved. It is not even known whether the chlorophyl is the same in all plants, nor why some leaves are evergreen and others fade invariably in the autumn.

Solution of chlorophyl, which may be made by macerating leaves in ether or other suitable solvent, possesses a fine green color, and gives in the spectroscope characteristic absorption bands.

ANIMAL CHEMISTRY.

The processes of animal life are more complicated than those of vegetable life. The animal has more functions; its vital action not only produces growth, but also renewal of tissue. The nourishing fluids in many animals are distributed, by mechanical action, to all parts of the body, and every part is under the influence of a central force called a nervous system. Animal structures are nitrogenous. The chief part of them are classed under the term *albuminoids* or *proteids.* They are very complicated in composition, containing carbon, hydrogen, oxygen, nitrogen, and sulfur, and are, therefore, prone to change, and capable of many modifications. Most of these modifications are capable of existing in both a soluble and insoluble state, and the different forms may be distinguished, to a certain extent, by the conditions under which each becomes insoluble. The important ones are:—

1. Albumin.—Blood and white of egg contain this body in the soluble form, but the albumin of blood, ser-albumin, is not exactly like that of white of egg, ov-albumin. A form like the latter occurs in plants. Heat and nitric acid make all these forms insoluble.

2. Globulin.—Exists in the crystalline lens and milk.

3. Vitellin.—In yolk of egg, in association with fat.

4. Casein.—Found in milk. It is not rendered insoluble by heat, but by dilute acids and certain ferments.

5. Fibrin.—Obtained from blood, and chyle, and lymph.

6. Peptones.—Formed by the action of gastric juice on proteids, and are, therefore, the result of digestion. They are not precipitated by ordinary acids.

Gelatin and Chondrin.—These are obtained by the action of hot water on skin, tendons, and bones. They contain no sulfur. Ordinary glue is a form of gelatin. Like the albuminoids, it exists in a soluble and insoluble modification; the latter form is produced especially by tannin, and upon this property the production of leather depends.

Cholesterol, $C_{26}H_{44}O$, probably $C_{26}H_{43}HO$.—This is a non-nitrogenous substance met with in many parts of the body. It is found in bile and blood, also largely in brain and nerve substance. It is a common product of putrefactive change in muscular tissue. Cholesterol is but slightly soluble in water, but easily soluble in alcohol or ether, from which it crystallizes in pearly plates, showing a somewhat fat-like appearance. It is not fat, being incapable of saponification. It is regarded as monatomic alcohol, $C_{26}H_{43}HO$. The radicle $C_{26}H_{43}$ is the twenty-fifth member of a series beginning with C_5H. Bodies homologous with cholesterol probably occur in animals. Compounds with acid radicles have been obtained by heating cholesterol with various acids. A sodium compound, $C_{26}H_{43}NaO$, analogous to sodium ethylate, is also known.

Taurin, $C_2H_7NSO_3$, is obtained from bile, in which it exists in association with cholates, constituting taurocholates. It crystallizes in prisms. It is soluble in water; the solution is neutral to test paper but acid in its structure. It dissolves sparingly in alcohol. When taurin is taken with food, the larger part of it is excreted by the urine in a peculiar combination with carbamic acid, which is related to urea. It is amido-ethylsulfonic acid, being derived by the substitution of NH_2 for one molecule of HO in acid ethyl-sulfate, as will be seen by contrasting the formulæ:—

Acid Ethyl Sulfate.	Taurin.
$C_2H_5HSO_4$	$C_2H_5(NH_2)SO_3$

It has been prepared synthetically.

Glycocin, $C_2H_5NO_2$, exists in bile, conjugated with cholates, as glycocholates. It may be separated by boiling the latter acid with barium hydrate, by which barium cholate is formed, and glycocin set free. It forms hard, granular, somewhat sweetish crystals, but slightly soluble in water. It gives, with strong solution of potassium hydroxid, an evanescent fiery-red color. It is amido-acetic acid, being derived by substituting one atom of H in acetic acid by NH_2, thus:—

Acetic Acid.	Glycocin (Amido-acetic Acid).
$C_2H_4O_2$.	$C_2H_3(NH_2)O_2$.

By the action of nitrous acid on a solution of glycocin, it is converted into nitrogen and glycolic acid, which is elsewhere given as a product of the oxidation of ethene glycol.

Leucin, $C_6H_{13}NO_2$.—This is found in various organs, and is present, sometimes, in the urine, especially in affections of the liver. It can be obtained by the decomposition of proteids, for instance, by boiling horn shavings with dilute sulfuric acid. It crystallizes in white shining plates, soluble in water. It forms compounds with both acids and bases. Its rational formula is $C_6H_{10}(NH)_2O_2$, being caproic acid, with one H replaced by NH_2, therefore amido-caproic acid.

Tyrosin, $C_9H_{11}NO_3$, is formed from albuminous bodies, at the same time that leucin is formed, by the action mentioned above. It also occurs in the urine, but only in association with leucin. Leucin, itself, sometimes occurs alone in urine. Tyrosin differs markedly from leucin in crystalline form, being deposited in fine, needle-like crystals, which form stellate masses. They are but slightly soluble in cold water; more so in hot. It combines both with acids and bases, forming, however, very unstable compounds. It is parahydroxybenzeneamidocaproic acid, $HO(C_6H_4)C_2H_3(NH_2)COOH$.

Leucin and tyrosin are formed when proteids are long subjected to action of the pancreatic ferment.

The different proximate principles found in organized tissues were formerly grouped under the general title, "Extractives."

COMPOSITION AND PROPERTIES OF SOME OF THE SOLIDS AND FLUIDS OF THE ANIMAL BODY.

BONES AND TEETH.—These consist principally of calcium phosphates, $Ca_3(PO_4)_2$, calcium carbonate, and organic matter. The following table gives the approximate proportions:—

	Young Child Femur.	*Adult Femur.*	*Adult Tooth.*
$Ca_3(PO_4)_2$	50	60	66
$CaCO_3$	6	8	5
$Mg_3(PO_4)_2$	1	1.5	1
Organic matter,	43	30.5	28

The teeth contain calcium fluorid and other matters not given in the table. The enamel contains only a few per cent. organic matter. It will be noticed that the bones gain in inorganic matter and lose in organic matter as the age advances. Hydrochloric acid will dissolve the mineral matter of bone, leaving the organic. Heated in contact with air, bone burns, leaving the mineral matter as bone-ash.

MUSCULAR TISSUE.—This is nearly three-fourths water, the solid part consisting of fibrin and albumin. Muscle is alkaline when at rest, but becomes acid during action.

A part of the liquid matter in flesh is the true *juice of flesh*. It has an acid reaction, and contains crystalline organic principles, among which are kreatin, inosite, together with potassium phosphate and other salts.

BRAIN AND NERVE TISSUE.

These are very complicated in structure. Brain contains about ninety per cent. water; the remainder includes proteid bodies, which are partly soluble, but mostly insoluble in water, phosphorized bodies, which are regarded as derivatives from glycerophosphoric acid, $C_3H_9PO_6$, various nitrogenous basic principles and inorganic salts.

Glycerophosphoric Acid, $C_3H_9PO_6$, may be regarded as glycerol in which one molecule of hydroxyl is substituted by the molecule H_2PO_4. It is, therefore, an acid phosphate. It has been obtained synthetically by the action of glycerol and phosphoric acid, the reaction being as follows:—

$$\overset{\textit{Glycerin.}}{C_3H_5(HO)_3} + \overset{\substack{\textit{Ortho-}\\\textit{phosphoric}\\\textit{Acid.}}}{H_3PO_4} = \overset{\substack{\textit{Glycerophosphoric}\\\textit{Acid.}}}{C_3H_5(HO)_2H_2PO_4} + H_2O.$$

The free acid is somewhat easily decomposed. The phosphorized principles in brain from which glycerophosphoric acid may be obtained, and which are regarded as derivatives from it are, kephalin, $C_{42}H_{79}PO_{13}$, myelin, under which term several bodies are included, and lecithin, $C_{43}H_{84}NPO_8$, which exists in egg matter as well as in brain.

Neurin, $C_5H_{13}NO$, is a basic substance existing in brain and also in yolk of egg. It possesses the general characters of an alkaloid.

Cerebrin.—Under this term are included several proximate principles, containing carbon, hydrogen, nitrogen, and oxygen. When placed in water they do not dissolve, but swell up very much. They yield glucose when heated with dilute acids, and are, therefore, nitrogenous glucosids.

Hypoxanthin, $C_5H_4N_4O$, and *inosite*, $C_6H_{12}O_6$, are found in other tissues besides brain. The first is a base. The inorganic constituents of brain are like those of the other tissues and fluids of the body, consisting of phosphates, sulfates, chlorids, etc., but copper is generally present in minute amount. Kephalin and lecithin are among the most important of the proximate principles existing in brain tissue. They are very complex in structure, a single molecule including fat-acid radicles, a phosphoric acid radicle, and a *substitution amin radicle.* Blyth has shown that sometimes in chronic lead poisoning the lead is in association with the kephalin, probably replacing some of the hydrogen.

Inosite is isomeric with glucose, but is not related to it. It is a benzene derivative.

BLOOD.

This, as the nourishing fluid of the animal, must contain all the materials necessary for the tissue, and, at the same time, it will always have more or less of the waste material in it. It is, therefore, very complicated. It consists of a clear liquid (*liquor sanguinis*), holding in *suspension* three forms of corpuscles, red, white, and transparent. The transparent form is nearly invisible. The liquid also holds in solution numerous organic and inorganic substances.

Elaborate tables have been given of the composition of blood, but the following is sufficient as an outline:—

The liquor sanguinis contains—

Water,	90.29
Albumin,	7.88
Fibrin,	0.40
Fat,	0.17
Mineral matter,	8.85
Extractive,	0.40

The corpuscles contain—

Water,	68.8
Globulin and cell membrane,	28.2
Hematin (including iron),	1.6
Fat,	0.2
Mineral matter (not including iron),	0.8
Extractive,	0.3

The "extractive" includes sugar, urea, and uric acid.

The specific gravity of the liquor sanguinis is about 1.028.

The blood is slightly alkaline when first drawn. Soon after leaving the body, the fibrin begins to solidify, and includes in its meshes the corpuscles, forming the clot, and leaving a clear liquid called serum. The cause of this coagulation is not well understood. It sometimes occurs within the body.

Hemoglobin or *Hematocrystallin* is the coloring matter of blood. It is remarkable for containing a small, but constant, amount—about 0.4 per cent.—of iron. According to Kingzett, the analyses of hemoglobin lead always to the formula $C_{600}H_{960}FeN_{154}S_3O_{177}$. It can be broken up into an albuminous body of unknown composition, and a crystalline substance known as *hematin*, $C_{32}H_{32}FeN_4O_6$.

Hemoglobin bears a very important relation to the function of respiration. It can combine readily with oxygen, forming oxyhemoglobin, the coloring matter of arterial blood. This oxyhemoglobin parts with its oxygen readily. This accounts for the readiness with which the transfer of oxygen through the blood occurs. Other gases, besides oxygen, are capable of combining with hemoglobin. One, carbon monoxid, unites with it so firmly that it cannot be easily displaced. Hence, when carbon monoxid is inhaled, death ensues from suffocation, because the hemoglobin is unable to give up the carbon monoxid and take the necessary amount of oxygen.

Hemin.—By boiling blood with glacial acetic acid and a small amount of sodium chlorid, the mixture, by evaporation to dryness, yields rhombic crystals, to which the composition of $C_{34}H_{36}N_4FeO_5Cl$ and the name hemin is assigned.

The albuminous principle in blood is a form called seralbumin. It can be precipitated by boiling, after the addition of a little acetic acid.

The mineral matters in blood are principally sodium chlorid, sodium carbonate, potassium phosphate, and potassium chlorid. Iron is always present, and is found only in the red corpuscles.

The gases of the atmosphere, especially oxygen, are present to a small extent in blood.

CHYLE AND LYMPH.

CHYLE is the fluid collected from the stomach and intestines, by the lymphatics arising from these organs. It is milk-like during digestion, owing to the presence of minute particles of oil. Chyle and lymph contain fibrin and are spontaneously coagulable. The analysis of chyle is as follows:—

Water,	90.48
Fibrin,	trace
Albumin,	7.08
Fats,	0.92
Extractives,	1
Salts,	0.44
	99.92

It has been calculated that about six and six-tenths pounds of chyle are formed and poured into the blood during the twenty-four hours. The fibrin is not found in chyle as first absorbed from the intestines, and appears to be formed, while passing through the thoracic duct, from the soluble albuminoids present. The extractives include urea, leucin, and tyrosin. The salts resemble those of blood. The fats occur perfectly emulsified.

LYMPH is regarded as the serum of the blood, which has been transuded into the tissues and reabsorbed and carried back into the circulation by the lymphatics. It is alkaline in reaction, and consists of a fluid and white corpuscles, much the composition, therefore, of diluted serum. It is a clear, straw-colored fluid, containing less fibrin and fatty matter than chyle. The fat occurs in globules. The average composition of lymph may be given as:—

	Water,	95.00
Solids	Albumin,	5.00
	Fibrin,	
	Fatty matter,	
	Salts,	
		100.00

MILK.

Milk is a liquid, secreted by a special gland, called the mammary gland, the presence and function of which are characteristic of a class of animals (*mammalia*) the highest in the scale of organic nature as known to us. It consists of a clear liquid, holding fat in suspension in the form of distinct globules, about .0002 of an inch in size, under conditions which prevent spontaneous coalescence. Its composition differs slightly in different animals, but, for the same animal, is pretty constant. Cow's milk has been most extensively studied. It and human milk are, of course, the most important. The composition of human milk is erroneously given by some authorities. The quantity of proteids does not usually exceed two per cent. The following table shows the comparison between cow's milk and human milk:—

	Cow's Milk.	Human Milk.
Fat,	3.9	3.5
Sugar,	4.3	6.5
Proteids,	3.8	1.6
Salts,	0.7	0.25
	12.7	11.85

The specific gravity of both milks is about 1.030.

The composition of the fat, and the general nature of the milk sugar, have been considered elsewhere. The proteids include casein, albumin, and globulin. The salts of milk are potassium and sodium chlorids and phosphates. The reaction of milk appears to be not constant; it is generally, but not always, slightly alkaline. If rendered distinctly acid, the casein becomes insoluble and precipitates, carrying with it most of the milk globules; the precipitate is the curd; the clear liquid, the whey. The relation, therefore, of fresh to curdled milk is somewhat like that of fresh to clotted blood, the butter globules corresponding to the corpuscles, and the casein to the fibrin. The so-called spontaneous curdling of milk occurs from the milk sugar undergoing the lactic acid fermentation, under the influence of microbes. In this fermentation of lactic acid some of the milk sugar is converted into glucose, and this latter may undergo conversion into alcohol. The alcoholic liquid thus obtained is called *koumis.* Milk is a nearly perfect diet, but is deficient in iron. Cream is only milk rich in oil globules. Normal milk sometimes becomes highly albuminous, and acquires a condition of "ropiness."

Colostrum, the first secretion of the mammary gland, is peculiar in several respects. It is denser than ordinary, the specific gravity being about 1.045 to 1.050. The fat is aggregated into much larger masses, and albumin is present, sometimes, in considerable amount.

DIGESTIVE SECRETIONS,

From the mouth to the terminus of the intestine extends an unbroken line of mucous membrane, every point of which possesses secretive powers more or less distinct in different parts. In addition to the various secretions thus introduced, a number of special glands located outside of the limits of the mucous membrane empty, by means of ducts, their secretions into the digestive tract. The first of these is the—

SALIVA.

Saliva is the secretion of several glands. It is obtained pure only with difficulty. Human saliva is a turbid, opalescent, viscid, and feebly alkaline fluid, of low specific gravity (1.005).

Ptyalin (*ptyalase*) is a ferment. Its composition has not been accurately determined. Its special function is the power of converting starch into sugar. Its solution is not coagulated by heating. The saliva also contains potassium *thiocyanate, KCNS,* the function of which is not known, While the secretions of the mouth remain alkaline there is a tendency to deposit calcium compounds on the teeth. This constitutes *tartar*, and although it protects the body of the tooth it has an injurious effect on the gums. Under some conditions the secretions of the mouth become acid; tartar is then no longer deposited, and the decay of the teeth is usually hastened.

GASTRIC JUICE.

Gastric juice is secreted by a special set of glands which are especially excited to action by the presence of food. The secretion is a thin, glairy fluid, of a yellowish tint and somewhat variable in composition. It is, as usually obtained for examination, mixed with some saliva. Its specific gravity is not constant, being generally about 1.010. It does not coagulate on boiling and is less liable to putrefaction than other secretions. The exact amount of gastric juice secreted in a given time and the composition of it is differently given by different authorities, partly on account of difficulty of obtaining it pure, partly because of the want of exact methods of analysis. Two important constituents are, however, characteristic of it, free hydrochloric acid and a nitrogenous ferment, pepsin (pepsase). The following is given as an analysis :—

Water,	99.44
Pepsin and other organic matter,	.32
Hydrochloric acid,	.25
Sodium chlorid,	.14
Potassium "	.05
Calcium "	.006
" and magnesium phosphates,	.015
	100.221.

Some observations indicate a variation of from 0.32 to 0.5 per cent. in the amount of hydrochloric acid, the average being about .17 per cent., or 1.7 per 1000. The quantity of the secretion has been estimated at from sixteen pounds to thirty-one pounds in the twenty-four hours. As mentioned above, the characteristic and important ingredients are the hydrochloric acid and pepsin. It appears, however, that other acids are occasionally present, especially lactic acid. The acidity has been ascribed to acid phosphates.

Pepsin (*pepsase*).—This is a nitrogenous ferment which may be obtained from the gastric juice of various animals. As usually obtained, it is a grayish-white or yellowish-white powder, insoluble in pure water, but soluble in dilute acids. Its important property is its power to render soluble and diffusible, proteids, such as white of egg. The presence of an acid is required for the process. The pepsin is not destroyed in the process, but appears to act only by its presence. The proteids are first changed into proteoses and then into peptones, but pepsin forms peptones rather slowly. The proportion of pepsin required to change a certain amount of proteid is very small. The process is **digestion**; it is exerted with nitrogenous forms of food; the oils, fats, starches, and sugars are not affected. The process of digestion is interfered with by the absence or great excess of free acid, and by the presence of alcohol.

BILE.

Bile is secreted by the liver, the largest secreting organ in the body. It is a yellowish-green, viscid liquid, of specific gravity about 1.020. If it be freed from intermixed mucus it loses its viscidity and shows but little tendency to putrefaction. It has a bitter taste and an alkaline reaction.

The quantity secreted is estimated at about forty ounces in twenty-four hours. This is all poured into the intestines, but the greater part of it is reabsorbed.

An important property of bile is its reaction with fatty substances. It emulsifies them, that is, breaks them up and renders them miscible with water. By such action the fatty matters of the food are subdivided sufficiently to allow of their absorption by the lymphatics of the intestine. In the intestinal canal, bile is supposed to act, in addition to its digestive functions, also as an antiseptic and mild stimulant to the muscular coat.

The inorganic constituents of bile are water, chlorids, and phosphates, and need no special mention. The principal organic constituents are sodium glycocholate and taurocholate, cholesterol, and several pigments. It contains no albumin. The glycocholate and taurocholate can be decomposed by sulfuric acid and the free acids thus obtained. Although not existing in bile in the free state, their properties are of interest, and have been alluded to in connection with the descriptions of taurin and glycocin. Taurocholic acid contains sulfur; glycocholic acid does not.

Bile Pigments.—Several bile pigments exist. Three have been distinctly indicated and analyzed, viz., *bilirubin*, *biliverdin*, and *bilifuscin*.

Bilirubin, $C_8H_9NO_2$.—This is, according to Thudichum, a monobasic acid, and exists in bile in the form of a calcium salt. When liberated by the action of acids it forms a powder of a brilliant red color, insoluble in water, alcohol, and ether, but soluble in chloroform. Nitric acid containing nitrous acid produces with bilirubin a play of colors, from green, through blue, violet and red, to yellow. The final product of the reaction is choletelin, said to be identical with urinary pigment. This reaction is utilized as a means of detecting traces of bile in organic fluids. Bilirubin is suppose to be the substance which gives the yellow color to the skin in jaundice.

Biliverdin, $C_8H_9NO_2$.—This coloring matter is produced when bilirubin is dissolved in caustic alkali and exposed to the action of oxygen for some time.

Bilifuscin, $C_9H_{11}NO_3$.—This coloring matter can be obtained directly from bile or from gall stones.

Sodium taurocholate and glycocholate give, with a mixture of sulfuric acid and sugar, a violet color, which has been called Pettenkofer's reaction. It was at one time supposed that bile products were the only ones that would give this, but other bodies which give it are now known. Still, with proper manipulation, this reaction is a good test for the presence of bile. Some substances give the reaction with sulfuric acid alone, but these are nearly all glucosids, and under the influence of the acid they yield the glucose which is necessary for the test.

PANCREATIC SECRETION.

Pancreatic Juice is a viscid alkaline secretion, of a specific gravity about 1.008. It contains about ten per cent. of solids, and, unlike bile and gastric juice, is very liable to putrefaction. Its functions are somewhat similar to those of the saliva; the pancreas has been called by physiologists the abdominal salivary gland. The exact composition of the secretion is not yet made out. It contains at least three digestive ferments: *trypsin* (trypsase), which has the power to convert proteids into peptones in alkaline solution, and is much more powerful than pepsin; a diastatic body, *amylopsin* (amylopsase), which converts starch into sugar, and a substance capable of emulsifying fats.

The amount secreted is small; about five ounces in the twenty-four hours.

THE INTESTINAL JUICE.

In addition to the digestive secretion considered above, the glands of the intestines throw out secretions amounting, according to some authorities, to ten ounces in the twenty-four hours. Very little is known of the composition of these secretions, on account of the difficulty of obtaining them pure and in sufficient quantity. Some writers have described the intestinal juice as a viscid, transparent, alkaline secretion, which is coagulated by some substances, and contains from two to two-and-a-half per cent. of solids. Its chemical action on the food is supposed to be about the same as that of the pancreatic juice.

EXCRETIONS.

A considerable number of products formed in the animal system are of such a character that they must be removed sooner or later from the body, or injury to health will result. For some of these the special secretory organs are provided, and, consequently, such products are both secretions and excretions. Two of these will be here considered: sweat and urine; the first the secretion of the skin, the second, of the kidneys. The two organs stand to each other in a vicarious relation; that is, one is capable, to a certain extent, of performing the functions of the other; but this substitution is not perfect.

SWEAT.

This term includes only the fluid portion of the secretion, but experiment has amply demonstrated that carbon dioxid is also given out, although only in small proportion. The water, for the most part, passes off in an insensible form, being carried away in solution in air surrounding the body; but when this air is saturated with moisture, or when the secretion of sweat becomes much increased, the water accumulates on the surface of the skin in the form of drops. From various experiments it has been concluded that the amount of water passed off by the skin in twenty-four hours is about two pounds; the amount of carbon dioxid is only about $\frac{1}{35}$ of that given off by the lungs. Very little is known about the solid contents of the sweat. Its composition is probably variable, even within the limits of health, and undoubtedly considerable changes take place in disease. The results of analyses are not very satisfactory. Urea is generally present in small amount, and the secretion is sometimes acid from the presence of free fat-acids.

URINE.

Characteristics of Normal Urine.—It is a clear, pale yellow or amber-colored fluid, of acid reaction. Its specific gravity within the limits of health may vary from 1.018 to 1.030. The quantity passed in the twenty-four hours by a male adult in good health may be approximately fixed at fifty fluid ounces —about fifteen hundred cubic centimetres.

The composition of the urine is very complex, and the published analyses are mostly unsatisfactory by reason of indefinite statements. It is convenient to divide the solid matters into two groups, organic and inorganic. The most important bodies in the former group are urea, uric acid, and creatinin. Urea is excreted in considerable amount (30 to 40 grammes per day in the case of a healthy male adult), but the excretion of uric acid and creatinin is far less. The inorganic ingredients consist of sulfates, chlorids and phosphates, potassium, sodium, calcium, and magnesium being the positives present; but it is not possible to state just how these combinations occur. It is believed that most of the chlorin occurs as sodium chlorid, the rest as potassium chlorid. Calcium and magnesium probably occur mostly as phosphates. Certain ethereal sulfates, especially phenyl sulfate, occur in small amount. Among the organic bodies often present in minute amount are acetone, aceto-acetic acid, indican, and hippuric acid. In addition to these ingredients many others are present in very minute amounts.

Urea, CH_4N_2O.—This is almost always present in the urine, and except in disease, is its most abundant solid constituent. It is isomeric with ammonium cyanate, $(NH_4)CNO$, and can be formed from it. Its rational formula is generally given as $(CO)H_4N_2$, being diamin, H_6N_2, in which two atoms of hydrogen are replaced by the acid radicle (CO). It ought, therefore, to be called carbonyl diamid. It is a colorless, easily crystallizable solid, soluble in its own weight of water; also soluble in alcohol. It is decomposed by heat and by many chemical agents. In the presence of putrefying or fermenting substances it takes up two molecules of water and becomes ammonium carbonate:—

$$CH_4N_2O + 2H_2O = (NH_4)_2CO_3.$$

The reaction does not occur with a pure solution of urea in water, but quickly occurs in ordinary urine, on account of the decomposition of the mucus. By this reaction stale urine becomes alkaline. With sodium hypobromite or hypochlorite, urea is decomposed, carbon dioxid and nitrogen being given off in the free state.

Urea is a base forming a series of well-marked salts, in which, as in the case of the organic bases generally, the acid unites without loss of hydrogen, but only one molecule of acid is taken up. Urea nitrate, for instance, is CH_4N_2O,HNO_3, and urea oxalate is $(CH_4N_2O)_2H_2C_2O_4$. These are but sparingly soluble in water. Urea exists in the urine in the free state.

Uric Acid, $H_2C_5H_2N_4O_3$.—This is contained in urine only in small quantity in health. It is a very common ingredient of urinary calculi and deposits. When pure it is a white, crystalline powder, almost insoluble in cold water. It forms two classes of salts, acid and normal. They are, in general, more soluble in water than the free acid. The normal urates are easily decomposed. When uric acid or urates precipitate from urine they generally carry down with them some of the coloring matters of the liquid.

Xanthin, $C_5H_4N_4O_2$, which differs from uric acid only by having one less atom of oxygen, is present in small amount in normal urine. Very rarely it is encountered as a form of calculus. It forms white, amorphous granules, and yields compounds with acids.

Hippuric Acid, $HC_9H_8NO_3$.—This substance is present only in small quantity in human urine, about one gram being passed daily.

Absolutely reliable analyses of urine can only be made on samples that are less than twenty-four hours old.

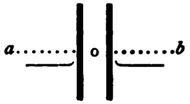
Samples of urine may be preserved by the addition of chloroform, a few drops to the fluidounce, but the sample must be thoroughly boiled before applying the copper or bismuth tests for sugar. Chloroform does not give the phenylhydrazin test.

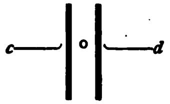
Specific gravity is generally taken by means of a urinometer, which is a graduated bulb-tube weighted so as to float upright. Extreme accuracy is not required, a difference of a few degrees not signifying anything clinically. In using the urinometer the following precautions are necessary:—

(*a*) The urine must be at a temperature near 60° F.; the determination should not be made when the liquid is first passed.

(*b*) The instrument must be placed in carefully, and the glass vessel must be wide enough to allow it to float freely.

In reading the degrees care should be taken to avoid error from the curved line which the liquid forms with the stem. Some urinometers are graduated to read at the highest point of this curve, others at the actual level of the liquid. To determine the proper method the instrument should be carefully floated in some distilled or rain water at a temperature of 60° and the position of the zero noted.





If the zero corresponds to the line *a b* each reading of gravity should be at the top of the curve, but if it corresponds to the position *c d*, then the reading should be along the real level of the liquid, and the eye should be placed on a line just below this level. If the zero point is at neither of the places noted the instrument is unsuitable for use.

The cheaper forms of urinometers are usually quite sufficient for clinical purposes.

Reaction.—Urine, when fresh, is generally decidedly acid, due, probably, to acid sodium phosphate, but when uric and hippuric acids are in excess they may also contribute to the acidity. The acid reaction increases slightly after the urine has been passed, but very soon the mucus begins to decompose and causes the urea to become ammonium carbonate. The liquid becomes alkaline and very foul. A neutral condition or transient alkalinity, called the alkaline tide, is seen in the urine secreted just after a meal, and an alkalinity due to decomposition is noticed in those cases in which, owing to obstruction, the liquid is retained in the bladder for some time.

For determining reaction, litmus paper is suitable. A solution of litmus is prepared by boiling it in water; this is divided into two parts, to one of which some strong acid is added, drop by drop, until the color is wine-red. This is then mixed with the other half of the liquid. Slips of filtering paper are dipped in this liquid and dried. They will assume a purple tint and are very delicate, responding either to a trace of free acid or of alkali. By employing this form of paper we avoid the necessity of using two colors. The paper should be cut into pieces about one-half an inch square, one of these being dipped into the sample to be tested. No piece should be used a second time. Litmus *paper* is best kept in a closed bottle away from the light, but litmus *solution* must be kept in an open bottle. It will then keep for a long time, while in a closed bottle it will soon decompose.

The principal coloring matter of normal urine is *urobilin*, an oxidation produced from blood. In febrile conditions a less oxidixed body occurs, which MacMunn has called *pathologic urobilin*.

Abnormal Coloring Matters.—These include various modifications of the blood-coloring matters, a special color known as uroerythrin, biliary products and colors due to articles of food.

Blood Colors.—These give to the urine a smoky color when in small amount; large quantities color it red.

When blood itself appears in urine the corpuscles may be recognized by the microscope, and the condition is called *hematuria*, but if only the coloring matters of the blood are present the condition is called *hematinuria*. In the latter case the abnormal ingredients are recognized by spectroscopic and chemical methods. A good test is to add to the liquid a small amount of tincture of guaiacum and a few drops of ether containing hydrogen dioxid. If blood products be present a blue color will be imparted to the ether. The ethereal solution of hydrogen dioxid may be easily prepared by shaking an amount of hydrogen dioxid solution with an equal volume of ether, and decanting the latter. The solution does not keep well. Care should be taken to use a good quality of hydrogen dioxid. Ten-volume solutions are now easily obtainable, but there is much inferior material on the market.

Biliary Coloring Matters.—When these are present in decided amount they give a yellow color to the urine. The test is fuming nitric acid, which gives a series of colors in the order, green, blue, violet, and yellow. The green color at the beginning is especially typical. The test is best performed by placing on a plate a drop or two of the urine and of the test liquid, and allowing the two to mingle slowly.

Chlorids are diminished during febrile conditions; sometimes entirely absent. They may be at once recognized by adding a few drops of nitric acid, and then silver nitrate. A white precipitate is formed if chlorids are present.

Sulfates. SO_4 occurs in urine in two forms of combination; ordinary sulfate, probably K_2SO_4, and as a compound ether with phenyl, probably potassium phenyl sulfate, $KC_6H_5SO_4$. This must not be confounded with phenol sulfonate, $KC_6H_5OSO_3$ with which it is isomeric.

Ordinary sulfates are detected by adding solution of barium chlorid and a few drops of hydrochloric acid to the filtered urine. A white precipitate (barium sulfate) shows sulfates. The ethereal sulfate does not respond to this test. By boiling the urine with hydrochloric acid the phenyl sulfate is broken up and will then give the barium reaction. This method is utilized for estimating the amount present. From the difference in weight between the barium sulfate produced from equal volumes of the sample with and without treatment with hydrochloric acid, the proportion of SO_4 present as phenyl sulfate may be calculated.

Phosphates.—Potassium and sodium phosphates are called alkaline phosphates; calcium and magnesium phosphates are called earthy phosphates. The former are freely soluble in water, but not all of the latter; both are soluble in acids.

The amount held in solution depends in part on the amount of acid, also on the temperature. These facts are important, because a deposit of phosphates may occur, either from alkalinity or deficient acidity of the urine, or from actual excess of the phosphates themselves. The clinical significance of these conditions is, of course, very different. By means of litmus, as already given, the reaction of the liquid can be easily ascertained. Deposits of phosphates are generally bulky and white, remaining undissolved when the liquid is boiled—being thus distinguished from urates—but dissolving in hydrochloric or nitric acid. Such deposits have no significance when found in urine which has become stale and has thus acquired an alkaline reaction.

Urine almost always produces a precipitate of earthy phosphates on boiling. The exact nature of the change is not certainly known, but it is probable that the urine contains calcium acid phosphate which breaks up into calcium diacid phosphate, that is freely soluble in water, and calcium phosphate that is insoluble. The reaction may be thus represented:—

$$2Ca_2H_2(PO_4)_2 = CaH_4(PO_4)_2 + Ca_3(PO_4)_2.$$

On adding a few drops of any strong acid the calcium phosphate passes into solution. By this means the precipitate may usually be distinguished from proteids.

Phosphates are found as deposits in various forms, which are, in the main, distinguishable from each other and everything else by the microscope.

Oxalates.—Calcium oxalate, CaC_2O_4, is the only one requiring notice. It is deposited in the minute but very distinct octahedral crystals and also in dumb-bell forms.

Uric Acid.—Excess of uric acid sometimes produces a brick-red deposit of small crystals. Under the microscope, even with a low power—40 to 60 diameters—these show various forms, generally lozenge-shaped.

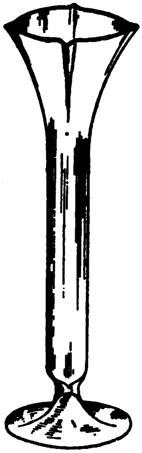
A deposit of urates may be recognized by the red color, and by dissolving in whole or in part by heating the liquid in which it is suspended.

Uric acid, or any of its compounds, may be recognized by the so-called *murexid test.* The sediment is treated on a watch glass or cover of a porcelain crucible, with a drop or two of nitric acid—not very strong—and then carefully evaporated to dryness. A drop of ammonium hydroxid is then added, and if uric acid is present a purple color will be produced.

Albumin.—The tests for albumin are dependent on its coagulation. The liquid should be filtered before the tests are applied and its reaction noted. Dr. D. D. Stewart has made careful studies of the tests for proteids in urine, and in this article I have quoted freely from his publications.

HEAT.—The most delicate clinical test is the simple one by heat, adding acetic acid beforehand, only if the specimen be but faintly acid, and then boiling the *upper stratum* in a long, narrow test-tube, subsequently comparing the upper and lower strata with the aid of a dark background. Should a cloud form, a few drops of a dilute solution of acetic acid should be added. No dependence is to be placed on a cloud appearing some time after the urine has cooled, if acetic acid has been added in any save the smallest amount. In the other event, the cloud is probably due to nucleo-albumin. The boiling test so used is very much more delicate than the nitric acid method. There is no test for serum-albumin without some source of fallacy. If much nucleo-albumin be present, and an excess of earthy phosphates, the heat test may mislead. Nucleo-albumin can usually be excluded by the use of citric acid, by the underlying method, to the cold urine.

NITRIC ACID, HELLER'S TEST.—This acid produces coagulation in the cold, and gives us a method but little liable to fallacy. About fifteen drops of commercial nitric acid are placed in a somewhat narrow test-tube, and about a drachm of urine poured slowly down upon it, holding the tube considerably inclined. Another method, and one preferred by many, is to put the urine in first and pour the acid down the side of the inclined tube, when it will run below the urine and form a clear layer at the bottom of the tube. For this and all other tests in which heat is not required, the test-tube designed by Mr. J. A. Kyner, of the Philadelphia Polyclinic, will be found very suitable. To use it the test material is put into the tube and then a piece of filter paper adjusted in the funnel-shaped top, so that the filtrate will run down the tube; the urine is then poured on the filter and will soon run through. Any precipitate at the point of contact will be at once seen. When no response is obtained the test-tube should be placed in hot water for a few moments and again examined. It must not be heated over a flame.



Fallacies.—Urine rich in urea sometimes gives a precipitate of urea nitrate, which might be mistaken for albumin. It can be distinguished by its solubility when warmed, and by its crystalline character.

Excess of urates may also produce a misleading precipitation, but the ring produced by these is generally more irregular, and after a few hours is converted into the crystalline uric acid, which is easily recognized under the microscope.

In exceptional cases resinous bodies which have been given as medicines may be found in the urine in combination with the bases present. Such compounds may be decomposed by the acid and the resin precipitated as an amorphous mass, which may simulate albumin. The distinction will be the odor of these resins and their solubility in strong alcohol. In addition to these points, the fact of their being administered will suggest precaution in regard to the test.

PICRIC ACID.—A saturated solution is a delicate test, but precipitates bodies other than albumin. This reagent is used by cautiously overlaying with the solution the urine to be tested. A cloud appears at the line of junction. It has been shown, that the non-albuminous urine of persons taking quinin will give a precipitation with this test; so also will the transformed albumins known as peptones. Nucleo-albumin reacts only slightly in the quantity in which it is present in urine. The negative evidence furnished by the test is often of value, as it saves more troublesome examination.

TRICHLORACETIC ACID, $HC_2Cl_3O_2$.—This is a white, crystalline, deliquescent solid, which dissolves easily in water. It is employed in saturated solution, which is easily prepared by allowing the solid to deliquesce by exposure to air. It is the most delicate test for proteids in urine irrespective of nature, but is too delicate for practical clinical work.

Of the proteid bodies usually occurring in urine, all but the peptones are precipitated by saturating the liquid with ammonium sulfate. This is easily done by adding the powdered material until no more is dissolved. Ovalbumin, seralbumin, paraglobulin, and the albumoses are separated, and may be collected on a filter. To detect peptones, the filtrate should be treated with a drop of a solution of copper sulfate and then considerable caustic soda added. A pink color shows the peptones.

To detect and distinguish the different proteids thrown down by the ammonium sulfate, the precipitate is washed, while on the filter, with some solution of ammonium sulfate and then dissolved by the addition of distilled water. Ovalbumin is coagulated by ether, seralbumin is not. Paraglobulin and albumose are precipitated by saturating the liquid with magnesium sulfate. By collecting the precipitate so formed, adding to it boiling water and adding a few drops of acetic acid, albumose will dissolve, paraglobulin will not.

In applying tests for minute amounts of proteids, it must be borne in mind that ordinary filter paper will yield to cold water sufficient vegetable albumin to react with delicate tests.

Nucleo-Albumin.—This body, commonly called mucin, is usually present in urine and simulates albumin in some of the tests. Its clinical chemistry has been fully discussed by Dr. D. D. Stewart, who employed a commercial nucleo-albumin obtained from bile and believed to be identical with that occurring in urine. He found that solutions of citric acid both dilute and concentrated used by the underlaying method, as described in connection with the nitric acid test for albumin, gave distinct contact rings. Picric acid associated with citric acid also gave such precipitates, but picric acid alone gave with solutions containing not more than .02 per cent. of nucleo-albumin only a tardily appearing haze.

Pus.—Pus is detected by the microscope, by which its cells may be seen in abundance; the liquid itself will give reactions for albumin. If a solution of caustic soda be added to urine containing pus, and the mixture poured a few times from one test to another, it will become very thick and viscid.

Sugar.—TROMMER'S TEST.—Add to about 1 fluidrachm of filtered urine enough copper sulfate solution to give a faint greenish-blue tinge, and then at least twenty drops of a strong solution of sodium hydroxid, and boil. If sugar be present, a greenish-yellow precipitate will form, which becomes, on further boiling, of a bright salmon color. If no sugar is present the precipitate will be bluish-green, and upon further boiling will turn black. A light brown, flocculent precipitate is often produced in urines free from sugar, and must not be mistaken for sugar reaction.

Allen recommends the following for doubtful cases: Heat to boiling ten c.c. of Fehling's solution, and add a nearly equal quantity of the urine; heat again for a few minutes, and allow to cool. If no turbidity is produced as the liquid cools, the urine contains less than $\frac{1}{10}$ of one per cent.

BOETTGER'S TEST.—Add to a filtered urine about half its volume of solution of caustic soda, and then a pinch of pure bismuth subnitrate. Shake the mixture and boil for a minute or so. Presence of sugar will be indicated by a *black* precipitate. If sugar is not present the precipitate will be white, or at most, somewhat gray. The action does not take place unless considerable free alkali is added. This test is very delicate and tolerably free from fallacy. Dark-colored urines of high gravity generally produce a gray precipitate, which might be mistaken as an indication of the presence of small amounts of sugar. The precipitate is not so heavy, and does not settle so rapidly nor so completely. For proper use it is well to purify the commercial bismuth nitrate by dissolving it in nitric acid, adding a few drops of hydrochloric acid, filtering and pouring the filtrate into a large volume of cold water. The precipitate collected, washed, and dried, is in excellent condition for use. Albumin, if present, must be removed before applying this test.

FERMENTATION TEST.—Yeast readily converts glucose into alcohol and carbon dioxid, and, since the latter is a gas, its production may be used as a means of detecting and estimating the glucose in urine. Normal urine gives some gas with yeast, and the fermentation test has no advantage over the regular chemical tests.

POLARIZATION TEST.—Reference is made in the article on the sugars to the rotation of the polarized ray, and since, under definite conditions, the degree of rotation is dependent on the amount of sugar present, it may be used as a means of detection and estimation. In practice, however, there are numerous difficulties. The apparatus is expensive and requires skill in use. Urine, especially in diseased conditions, contains bodies other than sugar which affect polarized light. Levulose, which has left-handed rotation, may be present and render the measurement valueless.

The optical and fermentation tests are quite unsuited to the determination of small amounts of sugar; the reducing tests are delicate, especially the bismuth tests, but there are several substances normally in urine, uric acid, xanthin, creatinin, and occasionally glycuronic acid, which simulate sugar very closely. To test properly, therefore, these bodies must be removed by methods which will not interfere with any sugar. Allen states that, according to Voit, creatinin may be excreted in quantity as high as five grams in twenty-four hours. This proportion would give a reducing action equal to 0.32 per cent. of glucose.

The following procedure for determination of sugar is partly that proposed by Maly, improved by G. Stillingfleet Johnson, and still further improved by Allen. Sixty c.c. of the urine are boiled for five minutes with 15 c.c. of saturated solution of mercuric chlorid and 3 c.c. of saturated solution of sodium acetate, and the liquid filtered while hot. This treatment precipitates the albuminous matters, phosphates, uric acid, xanthin, and congeners, creatinin, and most of the coloring matters. The material on the filter is twice washed and washings added to the filtrate. The liquid is then boiled for ten minutes with zinc dust (this is now a standard reagent easily obtained) and again filtered. The precipitate is washed, the washings added to the filtrate, and the whole liquid diluted to a definite volume, with which qualitative and quantitative tests may be employed.

PHENYLHYDRAZIN TEST.—Phenylhydrazin has the property of forming sparingly soluble crystalline compounds with the sugars. It was employed in the researches into the structure of the sugars, and is recommended by von Jaksch for clinical testing. The following method is substantially due to C. Schwartz: 10 c.c. of the urine are heated to boiling and treated with 5 c.c. of a 10 per cent. solution of lead acetate. The liquid is boiled and filtered hot. Solution of sodium hydroxid in amount sufficient to redissolve the precipitate, which first forms, is added to the filtrate, then as much phenylhydrazin hydrochlorid as will lie on the point of a penknife is dropped in. The liquid is then boiled for some minutes and then strongly acidulated with acetic acid. In the presence of much sugar an immediate yellow turbidity will be produced, but if only minute traces be present, a yellow coloration appears. The liquid on standing for some time becomes turbid. For positive identification, the precipitate, which is a compound of the sugar with the reagent, should be examined by the microscope to demonstrate its crystalline structure. .05 per cent. of glucose can be detected by this test. Dextrose and levulose give identical results. Glycuronic acid (a rare substance closely allied to glucose) and its derivatives also give the reaction, but these bodies are not fermentable by yeast.

On adding Fehling's solution to a liquid containing creatinin, a green liquid is produced, and on boiling a yellow color appears without separation of a precipitate of cuprous oxid.

Acetone.—This is generally present, but only in small amount. Two tests are available for its detection:—

LEGAL'S TEST.—Add to a portion of the sample a few drops of a freshly made solution of sodium nitroprussid and then a few drops of a strong sodium hydroxid solution. A ruby-red color usually appears which slowly fades to yellow. Acetic acid is then added, and if a purple or violet color is produced, acetone is present.

LIEBEN'S TEST.—This depends on the formation of iodoform. Alcohol gives the same reaction. A few c.c. of the urine are mixed with a little solution of iodin and potassium iodid in water, the mixture warmed slightly, then sodium hydroxid solution added until the liquid is decolorized. In the presence of alcohol or acetone a yellow precipitate subsides, which can be easily recognized as iodoform by its odor and by its six-sided crystals, visible under moderate magnifying power.

Dr. J. H. Long recommends that these tests be applied to liquid obtained by mixing a considerable volume of the urine with a little phosphoric acid, and distilling until about one-tenth of the volume has been collected.

Aceto-acetic Acid (Diacetic Acid).—The urine known to be free from unusual substances administered as remedies, the production of a wine-red color, on addition of a little ferric chlorid, indicates aceto-acetic acid. Its presence in urine is often noted in cases of diabetes, and it has considerable significance.

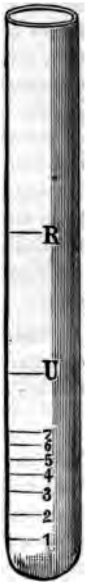
Indican.—This is a colorless body which, by action of acids, forms indigo blue. Of the tests for its detection that proposed by Jaffé is best: 10 c.c. of the urine are mixed with an equal volume of strong hydrochloric acid and about 3 c.c. of chloroform. Several c.c. of strong solution of chlorated lime (previously filtered) is then added, drop by drop, shaking after each addition. The mixture is then allowed to stand a few minutes, when the chloroform will collect at the bottom in a layer which will be more or less deeply blue in proportion to the indican present.

QUANTITATIVE ANALYSIS.

Albumin.—According to Hoffmann and Ultzmann, the white zone produced in the cold nitric acid test may be used as a fair approximation of the amount of albumin present. If this zone has the depth of from one tenth to one-eighth of an inch and appears clearly defined only against a dark ground, the amount of albumin is less than one-half of one per cent. If the zone be between one-sixth and one-quarter of an inch deep, granular, opaque, and visible without a dark background, the amount is about one-half per cent. If the albumin becomes flocculent and separates in lumps, the amount is from one to two per cent.

The quantity of albumin does not usually exceed one-half of one per cent. The practice of boiling the urine and, after adding acid, noting the bulk of the precipitate, is of no value. Such phrases as one-quarter or one-half albumin, often used to express these results, are incorrect.

Esbach's Method.—This depends on the volume of the precipitated albumin measured in a special form of tube called Esbach's albumometer. The manipulation is as follows: The tube is filled to the point U with the sample to be tested, and then to the point R with a liquid prepared by adding 1 gram of pure picric acid and 2 grams pure citric acid to 100 c.c. of water. If this solution is not clear it should be filtered before being used. After filling the tube as noted, it is closed with a good stopper, shaken several times, and then allowed to stand upright for twenty-four hours. The volume of the precipitate may then be read off on the special scale at the lower part of the tube. The observation must be made at ordinary temperatures and under the conditions noted. Urines very rich in albumin should be diluted with a definite volume of water, and this dilution allowed for. The method is fairly accurate for clinic purposes, especially for successive observations on the same case.



Sugar.—The most suitable method for clinical purposes is the volumetric estimation of Fehling's solution. This must be accurately made according to the following formula given by Allen, which agrees with the usual formula except that the amount of Rochelle salt is slightly increased. 34.64 grams of pure crystallized copper sulfate are dissolved in distilled water and the solution made up to 500 c.c. 70 grams of sodium hydroxid (in sticks) and 180 grams of Rochelle salt are dissolved in 400 c.c. of water and the solution made up to 500 c.c. Each solution should be kept in a well-corked bottle. For use, equal bulks of the two liquids are mixed. To determine the proportion of sugar, ten c.c. of the mixed solution is put into a porcelain basin, diluted with water, and the liquid brought to boiling; a few fragments of clay pipe may be added to prevent bumping. The urine diluted to five or ten its volume. according to probable amount of sugar present, is then added from a graduated burette in small amounts, the liquid boiled after each addition, and after a moment's rest the basin is tilted slightly, so that the color of the solution can be seen against the white surface. The porcelain dish with handle, called the casserole, is suitable for this work. If the liquid thus examined shows a blue tint, another portion of urine must be added, the mixture boiled, and the result noted as before. When no more blue tint is seen, the quantity of urine used should be noted and after carefully rinsing the basin the experiment is repeated for more accurate record. Each ten c.c. of Fehling's solution prepared as above is equal to 0.05 gram of sugar.

To get accurate results the quantity of sugar should not exceed one per cent.

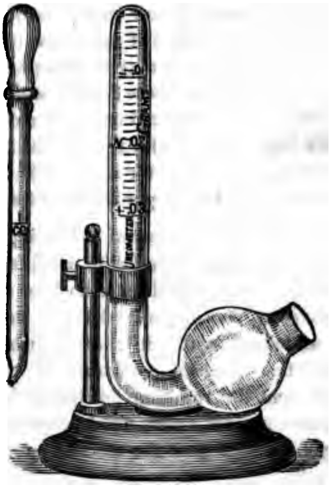
Urea.—Quantitative determinations are generally made by means of hypochlorites or hypobromites, which decompose the urea completely by the reaction:—

$$CH_4N_2O + 3NaClO = 3NaCl + CO_2 + 2H_2O + N_2.$$

If an alkaline solution is used the CO_2 will be absorbed, and the volume of N will be proportioned to the urea present. Hypochlorites do not produce so complete an action as hypobromites, so that the latter are usually preferred, although less convenient, requiring to be prepared as needed. The hypochlorite must contain excess of sodium carbonate. The formulæ given by the U. S. Pharmacopeias of 1870 and 1890 are correct; that of 1880 is unsuitable. It is stated that the commercial sodium hypochlorite, Labarraque's solution, may be made sufficiently active by adding potassium bromid in the proportion of one gram to twenty-five c.c. of the hypochlorite solution.

Many forms of apparatus have been suggested. The cut shows a simple one devised by Dr. C. A. Doremus.

Sodium hypobromite solution is prepared by dissolving 10 grams of sodium hydroxid in 25 c.c. of water, and adding cautiously 2.5 c.c. of bromin. It does not keep well, and, therefore, should be prepared as wanted, but it may be preserved for a short time in a tightly stopped bottle away from the light. Bromin is extremely irritating and corrosive, and the solution should be made in the open air or in a well ventilated apartment.



To use the apparatus, it is filled with the hypobromite solution so that when placed as in the cut, the liquid partly fills the large bulb. A large watch-glass, or shallow dish, may be placed under the tube to catch any overflow. A measured quantity of the urine is then introduced by means of the dropping tube, the opening of this being pushed well into the bend of the upright tube. It is well to tilt the apparatus a little forward to insure that no gas bubbles or urine escape into the large bulb. After about twenty minutes the volume of nitrogen gas is read off. 1 c.c. of nitrogen may be taken to correspond to .0028 of a gram (.04 grain) of urea. The method should be tried on samples of normal urine, to familiarize the operator with the manipulations. Doremus' apparatus is graduated to show actual amount of urea in grains or grams using 1 c.c. of the urine. Parke, Davis & Co. manufacture a convenient form and Dr. Squibb also furnishes one. Full directions for use accompany each instrument.

Dr. Chas. Rice advised the use of bromin dissolved in water by aid of potassium bromid. This being kept as a stock solution, measured portions of it containing the proper quantity of bromin can be conveniently employed. Squibb has investigated this method and finds it satisfactory. The solution may be prepared as follows: 10 grams of potassium (or sodium) bromid are dissolved in 80 grams of water, 10 grams of bromin added and the liquid shaken gently from time to time until the bromin is dissolved. When used in Squibb's apparatus, 3 c.c. of the sodium hydroxid solution (10 grams NaHO in 25 c.c. of water) are mixed with 3 c.c. of the bromin solution; after gently shaking, the mixture is ready for use. With Doremus' or Parke, Davis & Co.'s apparatus a somewhat larger amount of each must be used.

Phosphoric Acid.—The best process of estimating this body would be to acidify a known volume of the urine with nitric acid and add solution of ammonium molybdate. After standing for an hour or so in a warm place the precipitate—ammonium phosphomolybdate—is collected on a filter, washed with water acidulated with nitric acid, then dissolved in dilute ammonia. To this solution is added a mixture of magnesium sulfate and ammonium chlorid (1), and the resulting precipitate is collected on a filter, washed with very dilute ammonia water, dried, burned, and weighed. The weight multiplied by 0.64 will give the amount of phosphoric anhydrid, P_2O_5.

Several approximate methods have been devised.

For the so-called earthy phosphates, Hoffmann and Ultzmann recommend that a test-tube, about six inches in length, and three-quarters of an inch wide, should be filled one-third full with the clear urine, and a few drops of ammonium hydroxid or sodium hydroxid be added, and the mixture heated slightly. The phosphates will separate in flakes, and in fifteen minutes will have subsided, if the tube is left at rest. If the layer of sediment is about one-third of an inch high the amount is normal; any marked departure from this can be easily noted.

The alkaline phosphates may be estimated by adding to the urine about one-third its volume of a mixture made with about equal parts of magnesium sulfate, ammonium chlorid, and ammonium hydroxid, dissolved in about eight times the quantity of water. A normal quantity of alkaline phosphates will give with this mixture a uniformly *milky* appearance.

URINARY SEDIMENTS.

The sediments which form in urine may be either organized or unorganized. All the forms require the microscope for their satisfactory identification. The organized sediments are principally tube-casts, blood or other corpuscles, epithelial cells, and spermatozoids. Many matters entirely foreign to the urine may find their way into it, either by design or accident. I have known a deposit of collodion and iodoform to be mistaken for a urinary sediment, and attempts made to induce physicians to believe that a piece of brick was a urinary calculus. Those who use the microscope for urinary analysis should familiarize themselves with the appearance of common objects, such as hair of various kinds, cotton and other fibres, fragments of wood, milk globules, etc.

The unorganized sediments are principally uric acid, urates, phosphates, and oxalates. Uric acid is generally in lozenge- or boat-shaped crystals. Urates are indistinctly crystalline; phosphates are generally in distinct prismatic crystals; oxalates in small, regular octahedra.

URINARY CALCULI.

The common forms of urinary calculi are composed of either uric acid, earthy phosphates, or calcium oxalates. Potassium, sodium, or calcium urates may also be found, and two bodies—xanthin and cystin—are found quite rarely. The common calculi are generally mixtures of several of the above mentioned bodies. Calcium oxalate and uric acid often form the nuclei around which other matters deposit. The distinction of the different forms is based principally on the action of heat.

1. A portion of the calculus is heated to redness on a piece of platinum foil. *a.* No residue is left. See 2. *b.* A fixed residue is left. See 3.

2. Apply the murexid test, page 173. If this gives a result, the calculus is either uric acid or ammonium urate. If no result occurs, the substance is either xanthin or cystin. See 5.

3. Add a drop of hydrochloric acid to the residue when cold. *a.* It effervesces. The original body was either a urate or oxalate. See 4. *b.* It does not effervesce. The calculus is a phosphate. The result may be confirmed by dissolving a portion of the calculus in hydrochloric acid, and adding solution of ammonium molybdate; a yellow precipitate will be formed.

4. Apply the murexid test to a portion of the original body. If it responds, the body is a urate; if not, an oxalate.

5. The solution of the original body in nitric acid turns yellow on evaporation, and leaves a residue insoluble in potassium carbonate: xanthin. The solution in nitric acid turns dark brown and leaves a residue soluble in ammonium hydroxid: cystin.

ANTIDOTES TO COMMON POISONS.

Mineral Acids.—Baking soda, magnesia, chalk, lime, washing soda, soap.

Caustic Alkalies.—Weak acids, vinegar, lemon juice, fixed oils.

Oxalic Acid.—Lime, magnesia, chalk.

Carbolic Acid.—Sodium sulfate, oils, albumin.

Tartar Emetic.—Vegetable astringents, tannin, green tea.

Corrosive Sublimate.—White of egg or other form of albumin.

Copper Sulfate.—White of egg, oils.

Sugar of Lead.—Soluble sulfates, especially magnesium sulfate or sodium sulfate.

Arsenic.—Ferric hydroxid freshly prepared.

Silver Nitrate.—Common salt.

Iodin.—Flour paste or starch water.

Zinc Chlorid.—Albumin.

Phosphorus.—Magnesia, old oil of turpentine, sanitas fluid.

Alkaloids Generally.—Animal charcoal and vegetable astringents.

Hydrocyanic Acid.—A mixture of ferrous and ferric salts with sodium carbonate.

SYMBOLS, VALENCIES, AND ATOMIC WEIGHTS.

Element.	Symbol.	Valency.	Atomic Weight.	Element.	Symbol.	Valency.	Atomic Weight.
Aluminum, . .	Al	IV	27	Molybdenum,	Mo	II IV	95.5
Antimony, . .	Sb	III V	12	Nickel, . . .	Ni	II	58.6
Arsenum, . .	As	III V	75	Niobium, . .	Nb	V	94
Barium, . . .	Ba	II	137	Nitrogen, . .	N	III V	14
Beryllium, . .	Be	II	9	Osmium, . .	Os	VI	190.2
Bismuth, . .	Bi	III V	209	Oxygen, . .	O	II	16
Boron, . . .	B	III	11	Palladium, . .	Pd	II IV	106
Bromin, . .	Br	I	80	Phosphorus, .	P	III V	31
Cadmium, . .	Cd	II	112	Platinum, . .	Pt	IV	194.3
Cesium, . . .	Cs	I	132.5	Potassium, . .	K	I	39
Calcium, . . .	Ca	II	40	Rhodium, . .	Rh	II IV	104
Carbon, . . .	C	IV	12	Rubidium, . .	Rb	I	85
Cerium, . . .	Ce	II IV	140	Ruthenium, .	Ru	II IV	104.2
Chlorin, . .	Cl	I	35.5	Samarium, . .	Sm	III	150
Chromium, . .	Cr	IV	52	Scandium, . .	Sc	III	44
Cobalt, . . .	Co	II	59.1	Selenium, . .	Se	II IV VI	79
Copper, . . .	Cu	II	63.2	Silicon, . . .	Si	IV	28
Davyum, . .	Da		154	Silver, . . .	Ag	I	108
Didymium, .	Di	III V	144 5	Sodium, . . .	Na	I	23
Erbium, . . .	Er	III	166	Strontium, . .	Sr	II	87.5
Fluorin, . .	F	I	19	Sulfur, . .	S	II IV VI	32
Gallium, . . .	Ga	III	69	Tantalum, . .	Ta	III V	182
Germanium, .	Ge	II IV	72	Tellurium, . .	Te	II IV VI	125
Gold, ...	Au	III	196.7	Terbium, . .	Tr		148.8
Hydrogen, . .	H	I	1	Thallium, . .	Tl	I III	204
Indium, . . .	In	III	113.4	Thorium, . .	Th	II IV	231
Iodin, . . .	I	I	126.5	Tin, ...	Sn	II IV	118
Iridium, . . .	Ir	II IV	191	Titanium, . .	Ti	IV	48
Iron, ...	Fe	II IV	56	Tungsten, . .	W	IV	184
Lanthanum, .	La	III	138	Uranium, . .	U	II	238 5
Lead, ...	Pb	II	206.4	Vanadium, . .	V	III V	51.3
Lithium, . . .	Li	I	7	Ytterbium, .	Yb		173
Magnesium, .	Mg	II	24	Yttrium, . .	Y	III	89
Manganese, .	Mn	II IV	55	Zinc, ...	Zn	II	65
Mercury, . .	Hg	II	200	Zirconium, .	Zr	IV	89.5

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